Request by the University of Alaska to Allow the Incidental Take of Marine Mammals During a Marine Geophysical Survey across the Arctic Ocean, August–September 2005

submitted by

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to

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TABLE OF CONTENTS

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SUMMARY

The University of Alaska Fairbanks (UAF), with research funding from the National Science Foundation (NSF) and the Norwegian Petroleum Directorate (NPD), plans to conduct a multi-institution marine seismic survey across the Arctic Ocean from northern Alaska to Svalbard during the period 5 August to 30 September 2005. UAF requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey across the Arctic Ocean. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5). Portions of the seismic survey will be conducted in the Exclusive Economic Zones (EEZs) of the U.S.A. and Norway.

Numerous species of cetaceans and pinnipeds inhabit the Arctic Ocean. Several of these species are listed as "Endangered" under the U.S. Endangered Species Act (ESA) and may occur in certain portions of the survey area, including the sperm, bowhead, humpback, fin, sei, blue, and North Atlantic right whale. The leatherback turtle is another species of special concern that could potentially occur in the Norwegian Sea. UAF is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests" are set forth below. This includes descriptions of the specific operations to be conducted, the marine mammals occurring in the study area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on marine mammals.

I. OPERATIONS TO BE CONDUCTED

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

The University of Alaska Fairbanks (UAF), with research funding from the National Science Foundation (NSF) and the Norwegian Petroleum Directorate (NPD), plans to conduct a marine seismic survey across the Arctic Ocean from northern Alaska to Svalbard from ~5 August to 30 September 2005 (Fig. 1). This project will be operated in conjunction with a sediment coring project intended to collect paleoenvironmental and paleoceanographic evidence that will reveal information about the recent history of the Arctic Ocean and its climate during the last ten thousand years.

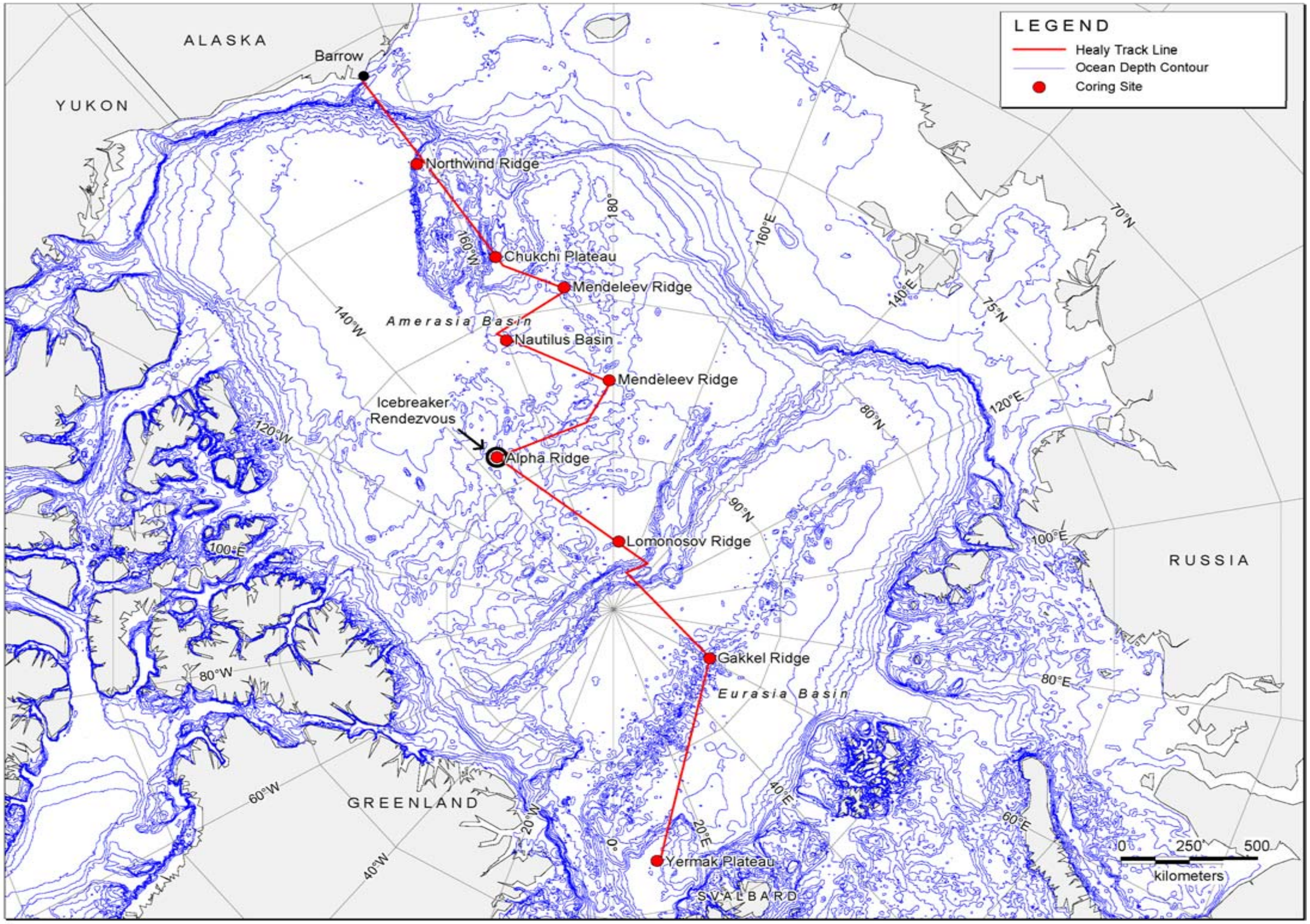


FIGURE 1. Proposed location of UAF's August-September 2005 Arctic Ocean seismic survey lines and coring areas. The precise track may vary somewhat from this nominal version depending on ice conditions.

The purpose of the proposed seismic study is to collect seismic reflection and refraction data that reveal the structure and stratigraphy of the upper crust of the Arctic Ocean. These data will assist in the determination of the history of ridges and plateaus that subdivide the Amerasian basin in the Arctic Ocean. Past studies have mapped the bottom of the Arctic Ocean, but data are needed to describe the boundaries and connections between the ridges and plateaus in the Amerasian basin and to study the stratigraphy of the smaller basins. This information will assist in preparing for future scientific drilling that is crucial to reconstructing the tectonic, magmatic and paleoclimate history of the Amerasian Basin.

The geophysical survey will involve the United States Coast Guard (USCG) cutter *Healy*. The *Healy* will rendezvous with the Swedish icebreaker *Oden* near Alpha Ridge (Fig. 1). The *Oden* will be working on a separate project, conducting an oceanographic section across the Arctic Ocean basin and will coordinate its timing to meet the *Healy*. The *Oden* will cut a path through the ice as necessary, leading the *Healy* for the remainder of the trans-ocean track past the North Pole and then on towards Svalbard. The two icebreakers working in tandem will optimize seismic data collection and safety through the heaviest multi-year ice.

The source vessel, the USCG icebreaker *Healy*, will use a portable Multi-Channel Seismic (MCS) system from the University of Bergen, provided through the NPD, to conduct the seismic survey. The *Healy* will tow two different airgun configurations. The primary energy source will be two G. guns, each with a discharge volume of 250 in^3 for a total volume of 500 in^3. The secondary energy source will be a single Bolt airgun of 1200 in^3 that will be used for deeper penetration over three ridges (the Alpha, Mendeleev, and Gakkel ridges).

The *Healy* will also tow a hydrophone streamer 100-150 m behind the ship, depending on ice conditions. The hydrophone streamer will be up to 300 m long. As the airguns are towed along the survey lines, the receiving system will receive the returning acoustic signals. In addition to the airguns, a multi-beam sonar and sub-bottom profiler will be used during the seismic profiling and continuously when underway.

The program will consist of a total of ~4060 km of surveys, not including transits when the airguns are not operating, plus scientific coring at nine locations (Fig. 1). The seismic survey will commence >40 km north of Barrow, Alaska, and the seismic activities will be completed northwest of Svalbard, in Norwegian territorial waters. Water depths within the study area are 20–4000 m. Little more than 1% of the survey (~48 km) will occur in water depths <100 m, 5% of the survey (~192 km) will be conducted in water 100–1000 m deep, and most (94%) of the survey (~3820 km) will occur in water >1000 m. There will be additional seismic operations associated with airgun testing, start up, and repeat coverage of any areas where initial data quality is sub-standard.

This is an NSF- and NPD-funded collaborative research effort that includes seismic activities by scientists from various international research institutions and universities. The chief scientists are Dr. Bernard Coakley of the University of Alaska Fairbanks, Dr. John Hopper of Texas A&M, and Dr. Yngve Kristoffersen of the University of Bergen. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

The coring operations (Table 1) constitute a separate project, also funded with an NSF grant, which will be conducted in conjunction with the seismic study from the *Healy*. Seismic operations will be suspended while the USCG *Healy* is on site for coring at each of nine locations. Depending on water depth and the number of cores to be collected, the *Healy* may be at each site for between 8 and 36 hours.

TABLE 1. Coring locations and approximate number of cores to be taken.

Coring Location	Location	Number of Cores
Northwind Ridge	74.5°N; 158°W	3
Chukchi Plateau	78.1°N; 163°W	3
Mendeleev Ridge (a)	79.5°N; 172°W	3
Nautilus Basin	80.75°N;160°W	3
Mendeleev Ridge (b)	82.6°N; 179°W	3
Alpha Ridge	84°N; 145°W	4
Lomonosov Ridge	87.8°N; 176°E	5
Gakkel Ridge	86.75°N; 61°E	3
Yermak Plateau	81.8°N; 9°E	3

Vessel Specifications

The *Healy* has a length of 128 m, a beam of 25 m, and a full load draft of 8.9 m (Fig. 2). The *Healy* is a USCG icebreaker, capable of traveling at 5.6 km/h (3 knots) through 1.4 m of ice. A "Central Power Plant", four Sultzer 12Z AU40S diesel generators, provides electric power for propulsion and ship's services through a 60 Hz, 3-phase common bus distribution system. Propulsion power is provided by two electric AC Synchronous, 11.2 MW drive motors, fed from the common bus through a Cycloconverter system, that turn two fixed-pitch, four-bladed propellers. The operation speed during seismic acquisition is expected to be ~6.5 km/h (3.5 knots). When not towing seismic survey gear or breaking ice, the *Healy* cruises at 22 km/h (12 knots) and has a maximum speed of 31.5 km/h (17 knots). She has a normal operating range of about 29,650 km (16,000 n.mi.) at 23.2 km/hr (12.5 knots).

The *Healy* will also serve as the platform from which vessel-based marine mammal observers will watch for marine mammals before and during airgun operations. The characteristics of the *Healy* that make it suitable for visual monitoring are described in § XIII, MONITORING AND REPORTING PLAN.

Other details of the *Healy* include the following:

Owner:	USCG
Operator:	USCG
Flag:	United States of America
Launch Date:	15 November 1997
Gross Tonnage:	16,000 LT
Bathymetric Survey Systems:	Seabeam 2112 Bottom Mapping Sonar, Odec Bathy 2000 Knudsen 320 B/R Sub Bottom Profiler
Compressors for Air Guns:	Portable University of Bergen Junkers compressors, capacity of 10 L/min at 140 bar
Accommodation Capacity:	138 including ~50 scientists

FIGURE 2. The source vessel, the U.S. Coast Guard Cutter *Healy*, to be used during the proposed August-September trans-Arctic Ocean seismic survey. Photograph from USCG *Healy* website at http://www.uscg.mil/pacarea/healy/.

Airgun Description and Safety Radii

The University of Bergen's portable MCS system will be installed on the *Healy* for this cruise. The *Healy* will tow either two Sodera 250 in^3 G. guns or a single 1200 in^3 Bolt airgun, along with a streamer containing hydrophones, along predetermined lines. Seismic pulses will be emitted at intervals of 20 s and recorded at a 2 ms sampling rate. The 20 s spacing corresponds to a shot interval of ~36 m at the typical cruise speed.

The two G. gun cluster will have a total discharge volume of 500 in^3; the single airgun will have a total discharge of 1200 in^3. The energy source will be towed as close to the stern as possible to minimize ice interference. The G. gun configuration will be towed below a depressor bird at a depth between 7 and 20 m depending on ice conditions; the preferred depth is 8–10 m deep. The two airguns will be towed one meter apart, separated by a spreader bar. The specifications for the different airgun configurations are shown below.

Received sound fields were modeled by Lamont-Doherty Earth Observatory (L-DEO) for the single 1200 in^3 Bolt airgun and for the one and two 250 in^3 G. guns that will be used at various times during this survey (Fig. 3, 4). For deep water, where most of the present project is to occur, the L-DEO model has been shown to be precautionary, i.e., it tends to overestimate radii for 190, 180, etc., dB re 1 µPa rms (Tolstoy et al. 2004a,b). Based on the models, the distances from the planned sources where sound levels of 190, 180, 170, and 160 dB re 1 µPa (rms) are predicted to be received are shown in Table 2. The rms (root-mean-square) pressure is an average over the pulse duration. This is the measure commonly used in studies of marine mammal reactions to airgun sounds, and in NMFS guidelines concerning levels above which "taking" might occur. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a).

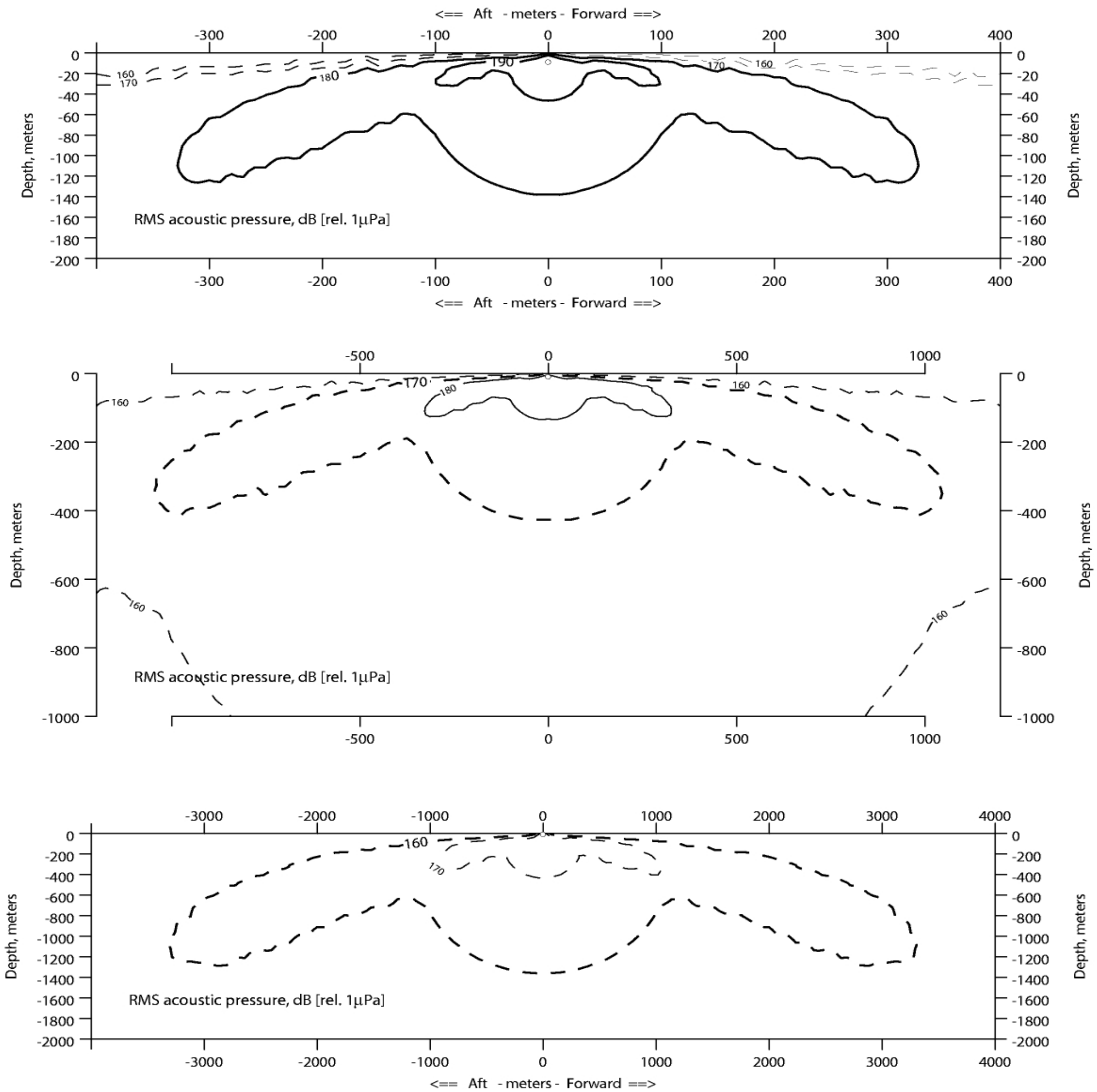


FIGURE 2. Modeled received sound fields from the two 250 in^3 G. guns that will be used during the UAF survey across the Arctic Ocean during 2005, assuming an operating depth of 9 m. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations. Model results are provided by the Lamont-Doherty Earth Observatory of Columbia University.

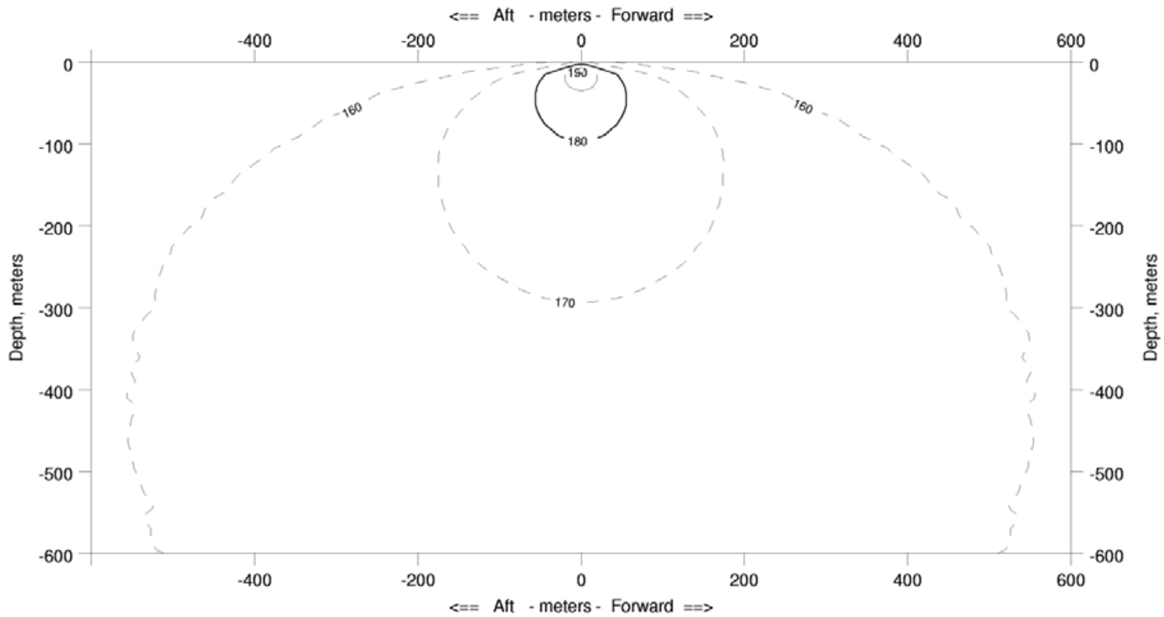


FIGURE 3. Modeled received sound fields from the single 1200 in^3 Bolt airgun that will be used during the UAF survey across the Arctic Ocean during 2005, assuming an operating depth of 10 m. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations. Model results are provided by the Lamont-Doherty Earth Observatory of Columbia University.

2 G. Gun Specifications

Energy source	Two G. guns of 250 in^3 each, firing every 20 s
Source output[1] (downward)[2]	0-pk is 6.5 bar-m (236 dB re 1 μPa-m); pk-pk is 11.7 bar-m (241 dB)
Towing depth of energy source	~9 m
Air discharge volume	500 in^3
Dominant frequency components	0–150 Hz

Single Bolt Airgun Specifications

Energy source	One Bolt airgun of 1200 in^3, firing every 30 s
Source output (downward)	0-pk is 5 bar-m (234 dB re 1 μPa-m); pk-pk is 11 bar-m (241 dB)
Towing depth of energy source	10 m
Air discharge volume	1200 in^3
Dominant frequency components	8–40 Hz

[1] For source at 5 m depth.

[2] All source levels are for a filter bandwidth of approximately 0-250 Hz.

TABLE 2. Estimated distances to which sound levels ≥190, 180, 170, and 160 dB re 1 μPa (rms) might be received from the 250 in^3 G. gun(s) and 1200 in^3 Bolt airgun that will be used during the seismic survey across the Arctic Ocean during 2005. The sound radii used during the survey will depend on water depth (see text). Distances are based on model results provided by the Lamont-Doherty Earth Observatory of Columbia University.

		Estimated Distances at Received Levels (m)			
Seismic Source Volume	Water depth	**190 dB** (safety criterion for pinnipeds)	**180 dB** (safety criterion for cetaceans)	**170 dB** (alternate behavioral harassment criterion for delphinids & pinnipeds)	**160 dB** (assumed onset of behavioral harassment)
250 in^3 G. gun	>1000 m	17	52	160	500
	100–1000 m	26	78	240	750
	<100 m	213	385	667	1364
500 in^3 2 G. guns	>1000 m	100	325	1050	3300
	100–1000 m	150	500	1600	5000
	<100 m	1500	2400	4500	9700
1200 in^3 Bolt airgun	>1000 m	25	50	175	560
	100–1000 m	38	75	263	840
	<100 m	313	370	729	1527

For the two G. gun source, the highest sound level measurable at any location in the water would be slightly less than the nominal source level because the actual source is a distributed source rather than a point source. However, the two guns would be only 1 m apart, so the non-point-source effect would be slight. For the single Bolt airgun, the source level represents the actual level that would be found about 1 m from the energy source. Actual levels experienced by any organism more than 1 m from either of the sources will be significantly lower.

The rms received levels that (at least in the U.S.A.) are used as impact criteria for marine mammals are not directly comparable to the peak or peak-to-peak values normally used to characterize source levels of airguns. The measurement units used to describe airgun sources, peak or peak-to-peak decibels, are always higher than the rms decibels referred to in much of the biological literature. A measured received level of 160 decibels rms in the far field would typically correspond to a peak measurement of about 170 to 172 dB, and to a peak-to-peak measurement of about 176 to 178 decibels, *as measured for the same pulse received at the same location* (Greene 1997; McCauley et al. 1998, 2000a). The precise difference between rms and peak or peak-to-peak values for a given pulse depends on the frequency content and duration of the pulse, among other factors. However, the rms level is always lower than the peak or peak-to-peak level for an airgun-type source.

The depth at which the source is towed has a major impact on the maximum near-field output, and on the shape of its frequency spectrum. In this case, the source is expected to be towed at relatively deep depths of 7 to 20 m.

Empirical data concerning the 190, 180, 170, and 160 dB (rms) distances in deep and shallow water have been acquired for various airgun configurations based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004a,b). Those were the data demonstrating that L-DEO's model tends to overestimate the distances applied in deep water. During that study, empirical data were not obtained for either the 1200 in^3 Bolt airgun or the G. guns that will be used during this survey. Although the results were limited, the calibration-study results showed that radii around the airguns where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), vary with water depth. Similar depth-related variation is likely in the 190 dB distances applicable to pinnipeds. Although sea turtle sightings are highly unlikely, the 180 dB distance will be used as the safety radius, as required by NMFS in another recent seismic project (Smultea et al. 2005).

The L-DEO model does not allow for bottom interactions, and thus is most directly applicable to deep water and to relatively short ranges. In intermediate-depth water a precautionary 1.5× factor will be applied to the values predicted by L-DEO's model. In shallow water, larger precautionary factors derived from the empirical shallow-water measurements will be applied. The proposed study area will occur mainly in water ~1000–4000 m deep, with only ~1% of the survey lines in shallow (<100 m) water and ~5% of the survey lines in intermediate water depths (100–1000 m).

- The empirical data indicate that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be precautionary pending acquisition of additional empirical data, it is proposed that safety radii during airgun operations in deep water will be the values predicted by L-DEO's modeling (Table 2). The estimated 190 and 180 dB radii for two 250 in^3 G. guns are 100 and 325 m, respectively. Those for one 1200 in^3 Bolt airgun are 25 m and 50 m, respectively.
- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results would be intermediate between those from shallow and deep water, a 1.5× correction factor is applied to the estimates provided by the model for deep water situations. This is the same factor that has been applied to the model estimates during L-DEO operations in intermediate-depth water from 2003 through early 2005. The assumed 190 and 180 dB radii in intermediate-depth water are 150 m and 500 m, respectively, for the two G. gun system and 38 m and 75 m, respectively, for the single Bolt airgun (Table 2).
- Empirical measurements were not made for the sources that will be employed during the proposed survey operating in ***shallow water*** (<100 m). The empirical data on operations of two 105 in^3 GI guns in shallow water showed that modeled values ***underestimated*** actual levels in shallow water at corresponding distances of ~0.5 to 1.5 km by a factor of ~3X (Tolstoy et al. 2004b). Sound level measurements for the 2 GI guns were not available for distances <0.5 km from the source. The radii estimated here for two G. guns operating in shallow water are derived from L-DEO's deep water estimates, with the same adjustments for depth-related differences in sound propagation used for 2 GI guns in earlier applications (and approximately

> the same factors as used for L-DEO's 10-airgun array). Similarly, the factors for the single airguns are the same as those for a single GI gun in earlier applications. Thus, the 190 and 180 dB radii in shallow water are assumed to be 1500 m and 2400 m, respectively for the two G. guns (Table 2). The corresponding radii for the single G. gun in shallow water are estimated to be 213 m and 385 m, respectively. The sound radii for the single Bolt airgun in shallow water are estimated to be 313 m for 190 dB and 370 m for 180 dB.

The airgun(s) will be powered down (or shut down if necessary) immediately when cetaceans, pinnipeds, or turtles are detected within or about to enter the appropriate radii. The 180 and 190 dB safety criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS.

UAF is aware that NMFS may release new noise-exposure guidelines soon (NMFS 2005). See http://mmc.gov/sound/plenary2/pdf/gentryetal.pdf for preliminary recommendations concerning the new criteria. UAF will be prepared to revise its procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required by the new guidelines, if issued.

Description of Operations

During the seismic survey across the Arctic Ocean, the *Healy* will deploy two different airgun configurations and tow a 300-m long hydrophone streamer. The survey well span from northern Alaska, to Svalbard, and will consist of a total of ~4060 km of surveys, not including transits when the airguns are not operating, plus scientific coring at nine locations (Fig. 1). The seismic survey will take place in water depths 20–4000 m, with >94% of the survey conducted in depths >1000 m.

The *Healy* will rendezvous with the *Oden* ~1167 km (630 n.mi.) off the coast of Alaska (Fig. 1). While the ships are operating together, *Oden* will sail ahead of the *Healy*, breaking ice. This will facilitate the *Healy's* collection of geophysical data. The *Oden* is a Swedish vessel that will not be governed by U.S. regulations during its survey with the *Healy*; joint operations by the *Oden* with the *Healy* will not commence until both vessels are well outside U.S. waters. The *Oden* will not be conducting seismic operations during the course of this project, but it will co-ordinate with the *Healy* and travel ahead of her during the remainder of the journey to Svalbard. Scientists aboard the *Oden* will be conducting independent oceanographic studies while leading the way through the ice. Prior to meeting the *Healy* in international waters near the end of August (28 or 29 Aug.), the scientific crew aboard the *Oden* will conduct studies in the Barrow area, working inland from Barrow on tundra ecology projects and visiting the Barrow Environmental Observatory. The *Oden* will serve as a work platform as part of a planned expedition, *Beringia 2005*, that is a joint Swedish-American-Russian project supported by the NSF and the Swedish Polar Research Secretariat. *Beringia 2005* is a follow-up to two earlier cruises supporting tundra ecology studies, along the Eurosiberian Arctic coast and through the Canadian Arctic archipelago and Nunavut. After the scientists aboard the *Oden* have completed their tundra ecology studies near Barrow, the *Oden* will depart for her rendezvous with the *Healy*, conducting oceanographic studies along the route until (and after) she joins the *Healy.*

Bathymetric Sonar and Sub-bottom Profiler

Along with the airgun operations, additional acoustical systems will be operated during much of or the entire cruise. The ocean floor will be mapped with a multi-beam sonar, and a sub-bottom profiler will be used. These two systems are commonly operated simultaneously with an airgun system. An acoustic Doppler current profiler will also be used through the course of the project.

Multi-beam Echosounder (SeaBeam 2112)

A SeaBeam 2112 multi-beam 12 kHz bathymetric sonar system will be used on the *Healy*, with a source output of 237 dB re 1 µPa at one meter. The transmit frequency is a very narrow band, less than 200 Hz, and centered at 12 kHz. Pulse lengths range from less than one millisecond to 12 milliseconds. The transmit interval ranges from 1.5 seconds to 20 seconds, depending on the water depth, and is longer in deeper water. The SeaBeam system consists of a set of underhull projectors and hydrophones. The transmitted beam is narrow (~2°) in the fore-aft direction but broad (~132°) in the cross-track direction. The system combines this transmitted beam with the input from an array of receiving hydrophones oriented perpendicular to the array of source transducers, and calculates bathymetric data (sea floor depth and some indications about the character of the seafloor) with an effective two-degree by two-degree foot print on the seafloor. The SeaBeam 2112 system on the *Healy* produces a useable swath width of slightly more than 2 times the water depth. This is narrower than normal because of the ice-protection features incorporated into the system on the *Healy.*

Sub-bottom Profiler (ODEC Bathy 2000)

The Ocean Data Equipment Corporation (ODEC) Bathy 2000 will provide information on sedimentary layering down to between 20 and 70 m, depending on bottom type and slope. It will be operated with the multi-beam bathymetric sonar system that will simultaneously map the bottom topography. The ODEC system has a maximum 7 kW transmit capacity into the underhull array. During normal operation, the operator adjusts the transmit level for optimum penetration into the seafloor. The energy from the sub-bottom profiler is directed downward from the transducer array mounted in the hull of the vessel. Pulse duration ranges from 0.5 to 25 milliseconds and the interval between pulses can range between 0.25 s and 10 s depending upon water depth. The swept (chirp) frequency ranges from 2.75 kHz to 6 kHz. The Bathy 2000 will be the primary unit used for seafloor sub-bottom mapping and the Knudsen 320BR (see below) will be used as back-up.

There is a single 12 kHz transducer and one 3.5 kHz, low frequency (sub-bottom) transducer array, consisting of 16 elements in a 4 × 4 array that will be used for either the ODEC Bathy 2000 or the Knudsen 320BR. The beamwidth propagated by the transducers will be the same for both sonar units. The 3.5 kHz transducer (TR109) emits a conical beam with a width of 26° and the 12 kHz transducer (TC-12/34) emits a conical beam with a width of 30°.

Hydrographic Echo Sounder (Knudsen 320BR)

The 320BR echosounder is a dual–frequency system with operating frequencies of 3.5 and 12 kHz. Maximum output power at 3.5 kHz is 10 kW and at 12 kHz is 2 kW. Pulse lengths up to 24 ms and bandwidths to 5 kHz are available. Pulse intervals are typically 1/2 s to about 8 s depending upon water depth. The repetition rate is range-dependent with a maximum 1% duty cycle. See above for beamwidth information.

12-kHz Pinger (Benthos 2216)

The Benthos 12-kHz Pinger will be used only during coring operations, to monitor the depth of the corer relative to the sea floor. The pinger is a battery-powered acoustic beacon that is attached to the coring mechanism. The pinger produces an omnidirectional 12 kHz signal with a source output of ~192 dB re 1 µPa-m at a one pulse per second rate. The pinger produces a single pulse of 0.5, 2 or 10 ms duration (hardware selectable within the unit) every second.

Acoustic Doppler Current Profiler (150 kHz Broad Band)

The 150 kHz Broad Band acoustic Doppler current profiler (ADCP™) operates at 150 kHz and has a minimum ping rate of 0.65 ms. There are four beam sectors and each beamwidth is 3°. The pointing angle for each beam is 30° off from vertical with one each to port, starboard, forward and aft. The four beams do not overlap. The 150 kHz Broad Band ADCP™'s maximum depth range is 300 m.

Acoustic Doppler Current Profiler (RD Instruments Ocean Surveyor 75)

The Ocean Surveyor 75 is an ADCP™ operating at a frequency of 75 kHz, producing a ping every 1.4 s. The system is a four-beam phased array with a beam angle of 30°. Each beam has a width of 4° and there is no overlap. Maximum output power is 1 kW with a maximum depth range of 700 m.

II. Dates, Duration, and Region of Activity

The date(s) and duration of such activity and the specific geographical region where it will occur.

The *Healy* will depart Seattle, WA, on an as-yet-undetermined date to rendezvous with the science party in Dutch Harbor, AK, on ~5 August 2005. The *Healy* will then sail north and arrive at the beginning of the survey, which will start >40 km north of Barrow, and possibly as much as 85 km farther north, depending on circumstances. From there, the entire cruise will last for ~53 days. It is estimated that the total seismic survey time will be ~26.1 days, assuming an average speed through the ice of 6.5 km/hr, or 3.5 knots. Estimated total time spent at the coring sites is ~10.6 days. The proposed plan is to extract thirty cores from nine locations along the seismic survey; numbers of cores will range from three to five at each of the coring sites (Table 1). During seismic operations the streamer will normally be recovered at the end of each seismic section, but in some situations, it may remain deployed between seismic lines although the airguns may be silent. Seismic survey work is scheduled to terminate northwest of Svalbard on or about 27 September. The vessel is expected to arrive in Tromsø, Norway, on 30 September 2005 after transiting from the last coring site on the Yermak Plateau.

The seismic survey will take place across the Arctic Ocean, extending from northern Alaska to Svalbard. The overall area within which the seismic survey will occur is located approximately between 71º25' and 81º49'N, and between 156º30'E and 9º44'W (Fig. 1). The bulk of the seismic survey will not be conducted in any country's territorial waters. However, the survey will occur within the Exclusive Economic Zone (EEZ) of the U.S.A. for approximately 356 km at the beginning of the cruise and within the Norwegian EEZ for ~152 km near the survey's terminus at Svalbard.

III. Species and Numbers of Marine Mammals in Area

The species and numbers of marine mammals likely to be found within the activity area.

A total of 17 cetacean species, 7 species of pinnipeds, and one marine carnivore are known to or may occur in or near the proposed study area (Table 3). Several of these species are listed as "Endangered" under the ESA: sperm, bowhead, humpback, sei, fin, blue, and North Atlantic right whale.

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in Section IV, below.

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition.

TABLE 3. The habitat, abundance, and conservation status of marine mammals inhabiting the proposed study area in the Arctic Ocean.

Species	Habitat	Abundance (Beaufort Sea)	Abundance (Svalbard/ Norwegian Sea/NE Atlantic)	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Sperm whale (*Physeter macrocephalus*)	Pelagic, deep seas	0	7785[4] 5200[5] 1542[6]	Endangered	VU	I
Beluga whale (*Delphinapterus leucas*)	Offshore, Coastal, Ice edges	50,000[7] 39,257[8]	300-3000[9]	Not listed	VU	
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	60,000[10]	100[43]	Not listed	DD	II
North Atlantic bottlenose whale (*Hyperoodon ampullatus*)	Continental shelf, submarine canyons	0	3142[12] 287[13] 40,000[14]	Not listed	LR-cd	I
Killer whale (*Orcinus orca*)	Widely distributed	Rare	6618[6] 3100[15]	Not listed	LR-cd	II
Long-finned pilot whale (*Globicephala melas*)	Mostly pelagic	0	778,000[16]	Not listed	-	II
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Shelf and slope waters	0	>100,000[17]	Not listed	-	II
Atlantic white-beaked dolphin (*Lagenorhynchus albirostris*)	Continental shelf	0	132,000[18]	Not listed	-	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal, inland waters	Extralimital	350,000[19]	Not listed	VU	II
Mysticetes Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	10,470[20]	Tens[5] 10[43]	Endangered	LR-cd	I
North Atlantic right whale (*Eubalaena glacialis*)	Coastal and shelf waters	0	250-300[21]	Endangered	EN	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	488[22] 17,500[44]	0	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore and banks	0	700[5] 1100[23] 1816[6]	Endangered	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	0	41,131[6]	Not listed	LR-cd	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	0	1000[24]	Endangered	EN	I
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	0	1906[5] 7167[6]	Endangered	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	0	1000[5] 442[6]	Endangered	EN	I
Pinnipeds Walrus (*Odobenus rosmarus*)		188,316[25]	15,000[26] <2000[27] 500-1000[28]	Not listed	-	II

Species	Habitat	Abundance (Beaufort Sea)	Abundance (Svalbard/ Norwegian Sea/NE Atlantic)	ESA[1]	IUCN[2]	CITES[3]
Bearded seal (*Erignathus barbatus*)	Pack ice	300,000-450,000[29] 4863[30]	300,000[41]	Not listed	-	-
Harbor seal (*Phoca vitulina*)	Coastal	N.A.	3800[31] 500-600[42]	Not listed	-	-
Spotted seal (*Phoca largha*)	Pack ice	1000[32]	0	Not listed	-	-
Ringed seal (*Pusa hispida*)	Landfast & pack ice	Up to 3.6 million [33] 245,048[34] 326,500[35]	1.3 million [36]	Not listed	-	-
Hooded seal (*Cystophora cristata*)	Pack ice	0	102,000[37]	Not listed	-	-
Harp seal (*Pagophilus groenlandicus)*	Pack ice	0	361,000[37]	Not listed	-	-
Carnivora Polar bear (*Ursus maritimus*)	Coastal, ice	1500-1800[38] 15,000[39]	2000[40]	Not listed	LR-cd	-

[1] Endangered Species Act.
[2] IUCN Red List of Threatened Species (2003). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).
[4] Abundance estimate for the Icelandic, Faroe Islands and Northeast Atlantic populations from Whitehead (2002).
[5] Abundance estimate for the Norwegian Sea from Christensen et al. (1992).
[6] Abundance estimate for Icelandic, Faroese, and adjacent waters from Gunnlaugsson and Sigurjónsson (1990).
[7] Total Western Alaska population, including Beaufort Sea animals that occur there in winter (Small and DeMaster 1995).
[8] Beaufort Sea population (IWC 2000).
[9] Svalbard population (Bjørge et al. 1991; IWC 2000).
[10] DFO 2004. This is mainly the population in Baffin Bay and the Canadian arctic archipelago; very few of these enter the Beaufort Sea.
[11] West Greenland population, World Council of Whalers.
[12] Icelandic population (Reyes 1991).
[13] Faroese population (Reyes 1991).
[14] Eastern North Atlantic population (NAMMCO 1995).
[15] Norwegian and Barents seas (Reyes 1991).
[16] Abundance estimate for the eastern North Atlantic from Buckland et al. (1993).
[17] Atlantic population (Cipriano 2002).
[18] Abundance estimate for all delphinids (consisting of about 90% white-beaked dolphins) in the Barents, eastern Norwegian, and North Sea (north of 56ºN) from Øien (1996 *in* Reeves et al. 1999b).
[19] North Sea population (Hammond et al. 2001, 2002).
[20] Abundance of bowhead whales surveyed near Barrow, as of 2001 (George et al. 2004).
[21] North Atlantic population (DFO 2004).
[22] Southern Chukchi Sea and northern Bering Sea (Clark and Moore 2002).
[23] Abundance estimate for the Northeast Atlantic from Øien (1990).
[24] Abundance estimate for Icelandic, Faroese and adjacent waters from Cattanach et al. (1993).
[25] Pacific walrus population (USFWS 2000a).
[26] Estimate for Atlantic walrus (Pagophilus.org).
[27] Svalbard-Franz Joseph Land population estimate (NAMMCO 1995).
[28] Eastern Greenland population estimate (NAMMCO 1995).
[29] Alaska population (MMS 1996).
[30] Eastern Chukchi Sea population (NMML, unpublished data).
[31] Abundance estimate for Norway from Reijnders et al. (1997 *in* Thompson et al. 1998a).

[32] Alaska Beaufort Sea population (MMS 1996).
[33] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).
[34] Bering/Chukchi Sea population (Bengston et al. 2000).
[35] Alaskan Beaufort Sea population estimate (Amstrup 1995).
[36] Eastern Canada and western Greenland estimate (NAMMCO n.d.).
[37] Abundance estimate for the Greenland Sea (NAMMCO 2001).
[38] Amstrup (1995).
[39] NWT Wildlife and Fisheries, http://www.nwtwildlife.rwed.gov.nt.ca/Publications/speciesatriskweb/polarbear.htm
[40] Polar bear status report for Svalbard, Polar Bears International, http://www.polarbearsinternational.org/facts.php
[41] Population estimate for the North Atlantic (Burns 1981).
[42] Svalbard population estimate (Henriksen et al. 1997).
[43] Svalbard population (CAFF n.d.).
[44] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2005).

The majority of the marine mammal surveys in the project area have been in the Beaufort Sea, generally within 100–200 km of shore. Few surveys have been conducted further north in waters toward the North Pole or north of Svalbard. Satellite-linked telemetry data have provided some information about the movements of certain marine mammal species in these more remote areas.

The marine mammals that occur in the proposed survey area belong to three taxonomic groups: odontocetes (toothed cetaceans, such as dolphins and sperm whale), mysticetes (baleen whales), and carnivora (pinnipeds and polar bears). Cetaceans and pinnipeds (except walrus) are the subject of the IHA Application to NMFS. Although detailed information on the walrus and polar bear are included here, they are managed by the U.S. Fish & Wildlife Service (USFWS).

The marine mammal species most likely to be encountered include four cetacean species (beluga whale, narwhal, killer whale, bowhead whale), five pinniped species (walrus, bearded seal, ringed seal, hooded seal, harp seal), and the polar bear. However, most of these will occur in low numbers and are most likely to be encountered within 100 km of shore. The most abundant marine mammal likely to be encountered throughout the cruise is the ringed seal. The most widely distributed marine mammals are expected to be the beluga, ringed seal, and polar bear.

About 13 additional cetacean species could occur in the project area, but are unlikely to be encountered along the proposed trackline; if encountered at all, those species would be found only near one end of the track, either near Svalbard or near Alaska. The following 12 species, if encountered at all, would be found close to Svalbard: sperm whale, northern bottlenose whale, long-finned pilot whale, Atlantic white-sided dolphin, Atlantic white-beaked dolphin, harbor porpoise, North Atlantic right whale, humpback whale, minke whale, sei whale, fin whale, and blue whale. Likewise, the gray whale is unlikely to be encountered, and if it is encountered, it would only occur near Barrow, Alaska. Two additional pinniped species, the harbor seal and spotted seal, are also unlikely to be seen.

(1) Odontocetes

(a) Sperm Whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). They range as far north and south as the edges of the polar pack ice, although they are most abundant in tropical and temperate waters where temperatures are >15ºC (Rice 1989). Sperm whale distribution is linked to social structure; females and juveniles generally occur in tropical and subtropical waters, whereas males are wider ranging and occur in higher latitudes (Harwood and Wilson 2001; Waring et al. 2001). In the North Pacific Ocean, sperm whales are distributed widely, with the northernmost occurrences at Cape Navarin (62ºN) and the Pribilof Islands (Omura 1955). Sperm whales do not occur in the Beaufort Sea or the Arctic Ocean. There have been occasional sightings of male sperm whales near Svalbard and in the Barents Sea (WWF Arctic Programme 2002).

During surveys of the Norwegian Sea in 1989, the main concentration areas for sperm whales, especially in the summer, were west of the continental slope in northern Norway and northwest of Møre, in southern Norway (Øien 1990; Christensen et al. 1992; see also Stone 2003). The total abundance in the Norwegian Sea was estimated by Christensen et al. (1992) to be 5200 sperm whales, of which about 1000 occur in the southern part of the Norwegian Sea. Øien (1990) gave an estimate of 2500 individuals for the northern Norwegian Sea. Gunnlaugsson and Sigurjónsson (1990) gave an abundance estimate of 1542 for Icelandic, Faroese, and adjacent waters. Mean school sizes in the Norwegian Sea range from 1.0 to 1.6 animals (Christensen et al. 1992).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography (Jacquet and Whitehead 1996). They routinely dive to depths of hundreds of meters and may occasionally dive to depths of 3000 m (Rice 1989). They are capable of remaining submerged for longer than two hours, but most dives probably last 30 min or less (Rice 1989).

The diet of sperm whales consists mainly of mesopelagic and benthic squids and fishes. Sperm whales are thought to forage for prey in a large part of the water column below the scattering layer (Wahlberg 2002). During a study on the acoustic behavior of diving sperm whales off northern Norway, Wahlberg (2002) noted that feeding events occurred at depths of 278 to 1245 m. Vertical swim speed for sperm whales was found to range from 0.8 to 1.4 m/s (Wahlberg 2002).

Sperm whales occur singly (older males) or in groups of up to 50. Christal et al. (1998) noted that typical social unit sizes ranged from 3 to 24. Sperm whale distribution is thought to be linked to social structure. Males are commonly alone or in same-sex aggregations, often occurring in higher latitudes outside of the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Males may migrate north in the summer to feed. Mature sperm whales begin to migrate to warmer waters to breed when they are in their late twenties (Best 1979), returning to colder waters to feed after the breeding season. They typically move between mixed schools, and only spend a short period of time with them (Whitehead 1993). Sperm whales are seasonal breeders, but the mating season is prolonged. In the Northern Hemisphere, conception may occur from January to August (Rice 1989), although the peak breeding season is April–June (Best et al. 1984). Females bear a calf every 3–6 years (Rice 1989).

Sperm whales produce acoustic clicks when underwater, probably for locating prey and communicating (Backus and Schevill 1966; Møhl et al. 2003). In the Galapagos Islands, sperm whales start to click regularly when they were 150–300 m deep (Papastavrou et al. 1989), which may indicate that the sperm whales were echolocating for food at those depths (Backus and Schevill 1966; Weilgart and Whitehead 1988; Smith and Whitehead 1993). On the breeding grounds, mature males produce "slow clicks" (Whitehead 1993) in the frequency range 0.1–30 kHz (review by Thomson and Richardson 1995).

Commercial whaling severely reduced the abundance of sperm whales. Whitehead (2002) estimated that the worldwide stock was 32% of its original level in 1999, ten years after the end of large-scale hunting. The sperm whale is the only species of odontocete discussed here that is listed under the ESA, and the only species of odontocete that is listed in CITES Appendix I (Table 3). Although the species is formally listed as ***Endangered*** under the ESA, it is a relatively common species on a worldwide basis, and is not biologically endangered.

(b) Beluga (*Delphinapterus leucas*)

The beluga whale is an arctic and subarctic species that includes several populations in Alaska and northern European waters. It has a circumpolar distribution in the Northern Hemisphere and occurs between 50º and 80ºN (Reeves et al. 2002). It is distributed in seasonally ice-covered seas and migrates to warmer coastal estuaries, bays, and rivers in summer for molting (Finley 1982).

Townsend (1935) stated that, in the eastern North Atlantic, belugas are rarely found south of 56ºN. In the eastern North Atlantic, belugas typically occur in the Barents Sea, off Svalbard, and near Finnmark (Øritsland et al. 1989; Øien 1990), where they are thought to summer (Gurevich 1980). Nishiwaki (1972) noted that belugas are abundant along the northern coast of Norway, and Gurevich (1980) indicated that belugas may move along the coast of Norway seasonally. Although they are not typically seen in the southern Norwegian Sea, extralimital records exist for Iceland, the Baltic Sea, Gulf of Bothnia, and the U.K. (Gurevich 1980; Reeves et al. 2002). Belugas typically are not sighted along the northern or eastern coast of Greenland (Culik 2002).

The Svalbard population of beluga whales is estimated at 300–3000 animals (Bjørge et al. 1991; IWC 2000)

In Alaska, beluga whales comprise five distinct stocks: Beaufort Sea, eastern Chukchi Sea, eastern Bering Sea, Bristol Bay, and Cook Inlet (O'Corry-Crowe et al. 1997). For the proposed project, only the Beaufort Sea stock and eastern Chukchi Sea stocks will be encountered. Some eastern Chukchi Sea animals enter the Beaufort Sea in late summer (Suydam et al. 2001).

The Beaufort population was estimated to contain 39,258 individuals as of 1992 (Angliss and Lodge 2002). This estimate is based on the application of a sightability correction factor of 2× to the 1992 uncorrected census of 19,629 individuals made by Harwood et al. (1996). This estimate was obtained from a partial survey of the known range of the Beaufort population and may be an under-estimate of the true population size. This population is not considered by NMFS to be a strategic stock and is believed to be stable or increasing (DeMaster 1995). The eastern Chukchi Sea stock population is estimated at 3700 (IWC 2000).

Beluga whales from the eastern Chukchi Sea stock are an important subsistence resource for residents of the village of Point Lay, adjacent to Kasegaluk Lagoon, and other villages in northwest Alaska. Each year, hunters from Point Lay drive belugas into the lagoon to a traditional hunting location. The belugas have been predictably sighted near the lagoon from late June through mid to late July (Suydam et al. 2001). Lowry (2001) tagged five male belugas with satellite tracking devices in Kasegaluk Lagoon in June/July 1998. Using the telemetry location of one beluga that remained relatively nearshore, a group of 11,035 animals were located and counted during an aerial survey near Icy Cape and in the ice just offshore on 6 July (Lowry et al. 1999 *in* Lowry 2001). Four of the tagged belugas moved far north into deep offshore Arctic Ocean waters with heavy ice cover (more than 90%), north of Point Barrow. Three of the five tagged belugas traveled north of 80°N, about 1100 km north of the Alaska coast. One of those belugas remained at 80°N for a week; it was speculated that this whale was taking advantage of a resource there, perhaps Arctic cod. The abundance estimate considered the "most reliable" for the eastern Chukchi Sea beluga whale stock is 3710, a result from 1989–1991 aerial surveys (Angliss and Lodge 2004). The population size is considered stable. It is possible that whales of the eastern Chukchi Sea beluga stock will be encountered during the early stages of the seismic survey in early August.

Beluga whales of the Beaufort stock winter in the Bering Sea, summer in the eastern Beaufort Sea, and migrate around western and northern Alaska (Angliss and Lodge 2002). The majority of belugas in the Beaufort stock migrate into the Beaufort Sea in April or May, although some whales may pass Point Barrow as early as late March and as late as July (Braham et al. 1984; Ljungblad et al. 1984; Richardson et al. 1995).

Much of the Beaufort Sea seasonal population enters in the Mackenzie River estuary for a short period during July–August to molt their epidermis, but they spend most of the summer in offshore waters of the eastern Beaufort Sea and Amundsen Gulf (Davis and Evans 1982; Harwood et al. 1996; Richard et al. 2001). Belugas are rarely seen in the central Alaskan Beaufort Sea during the summer. During late summer and autumn, most belugas migrate far offshore near the pack ice front (Frost et al. 1988; Hazard 1988; Clarke et al. 1993; Miller et al. 1998). Moore (2000) and Moore et al. (2000b) suggest that beluga whales select deeper slope water independent of ice cover. However, during the westward migration in late summer and autumn, small numbers of belugas are sometimes seen near the north coast of Alaska (e.g., Johnson 1979). Nonetheless, the main fall migration corridor of beluga whales is ~100+ km north of the coast. Satellite-linked telemetry data show that some belugas migrate west considerably farther offshore, as far north as 76ºN to 78ºN latitude (Richard et al. 1997, 2001).

Pod structure in beluga groups appears to be along matrilineal lines, with males forming separate aggregations. Small groups are often observed traveling or resting together. Belugas often migrate in groups of 100 to 600 animals (Braham and Krogman 1977). The relationships between whales within groups are not known, although hunters have reported that belugas form family groups with whales of different ages traveling together (Huntington 2000). During surveys conducted in the Mackenzie estuary and west Amundsen Gulf in July 1992 (Harwood et al. 1996), beluga whales were widely distributed at low densities of 0.099–0.311 beluga/km^2.

Although beluga whales are largely absent from the central Alaska coast during the summer, a few beluga whales could be encountered during the first part of the proposed cruise, from the Alaskan coast to ~80ºN, or during the latter stages of the cruise near Svalbard.

(c) Narwhal (*Monodon monoceros*)

Narwhals have a discontinuous arctic distribution (Hay and Mansfield 1989; Reeves et al. 2002). A large population inhabits Baffin Bay, West Greenland, and the Canadian Arctic archipelago, and much smaller numbers inhabit the Northeast Atlantic/East Greenland area. The species is rarely seen in Alaskan waters or the Beaufort Sea. Thus, the portion of the cruise track where narwhals are most likely to be encountered is near the end of the seismic survey north of Svalbard.

Observations by Gjertz (1991) suggest that, near Svalbard, narwhals concentrate in the northwest area of Spitzbergen. Along the east coast of Greenland, narwhals range from Nordostrundingen (81°N) south to Umiivik (64°N), and from there eastwards in the high arctic pack ice through the Greenland, Barents, Kara, Laptev and East Siberian seas to ~165°E, and from ~85°N southward to Svalbard, Zemlya Frantsa Iosifa, Novaya Zemlya, Severnaya Zemlya, Novosibirskiye Ostrova, and Ostrova De-Longa (157°E; Rice 1998). Extralimital records exist for Iceland, the Norwegian Sea, and the North Sea, including the British Isles (Rice 1989; Reeves et al. 2002).

Narwhal movements follow the sea ice. In the spring, as the ice breaks up, they follow the receding ice edge and enter deep sounds and fjords, where they stay during the summer and early fall (Reeves et al. 2002). When the ice reforms, narwhals move to offshore areas in the pack ice (Reeves et al. 2002), living in leads in the heavy pack ice throughout the winter. Most pods consist of 2–10 individuals but they may aggregate to form larger herds of hundreds or even thousands of individuals (Jefferson et al. 1993). According to Hay (1985), segregation by age and sex within this population is evident, with summering groups consisting of mature females with calves, immature and maturing males, and large mature males.

Population estimates for the narwhal are scarce and the IUCN lists the species as Data Deficient (IUCN 2003). The population in eastern Greenland was conservatively estimated as 176 (Hay and Mansfield 1989), but that number is likely to be a considerable underestimate. Born (1994) indicated that narwhals in that region prefer areas distant from the coast and number a few thousand individuals. The Canadian and western Greenland population is believed to be in excess of 40,000 animals, with a point estimate of 45,358 whales (Koski and Davis 1994; Innes et al. 2002). The eastern Greenland narwhal population is considered a discrete stock, separate from the Canadian and western Greenland population.

No narwhals are likely to be encountered during the Alaska portion of the proposed activity, and only a few are likely to be encountered toward the end of the trackline, south of 85°N. During the late summer-early autumn, when the proposed cruise will be approaching Svalbard, narwhals are expected to be largely coastal in their distribution.

(d) Northern Bottlenose Whale (*Hyperoodon ampullatus*)

Northern bottlenose whales are found in the North Atlantic, mainly in cold temperate, subarctic, and polar waters (Reeves et al. 1993, 2002). Reeves et al. (1993) report that they occasionally enter pack ice off Svalbard and Labrador. They occur off Iceland, the west coast of Spitzbergen, Jan Mayen, the coast of Norway, and the Faroe Islands (Mead 1989). Northern bottlenose whales appear to migrate latitudinally, moving south in the fall and north in the spring (Thompson et al. 1998a; Jonsgård and Øynes 1952 *in* Reid et al. 2003). Estimates for Icelandic and Faroese waters are 3142 and 287 whales, respectively, although allowance was not made in the surveys for animals not observed because of their long dives (Reyes 1991). The North American Marine Mammal Commission (NAMMCO) has calculated the population size of this species in the eastern part of the North Atlantic to be around 40,000 individuals (NAMMCO 1995). Carwardine (1995) noted that there are certain pockets of abundance, including southwest of Svalbard.

During surveys of the Northeast Atlantic, Øien (1990) noted bottlenose whale sightings at Jan Mayen and in the western part of the Norwegian Sea; group sizes ranged from 2 to 7, with a mean of 4.43. Christensen (1977) noted a sighting of this species offshore from Lofoten, Norway. Stone (2003) noted sightings of bottlenose whales southeast of the Faroe Islands. Skov et al. (1995) also noted the occurrence of this species north of the Faroe Islands in water >1500 m deep. Northern bottlenose whales have been reported to enter the pack ice off Svalbard and Labrador on occasion (Reeves et al. 1993). Bottlenose whales are known to inhabit deep waters (Benjaminsen and Christensen 1979), usually near the 1000 m isobath (Reeves et al. 1993; Reid et al. 2003). They feed on squid, and their distribution may be influenced by the distribution of their most common prey, the squid *Gonatus fabricii* (Harwood and Wilson 2001).

The deep waters west of the shelf at Spitzbergen and the slope off Lofoten and Møre used to be important whaling areas (Benjaminsen and Christensen 1979). However, bottlenose whales are migratory in this area, entering these waters in spring with peak abundances in early summer (Evans 1980; Øien 1990). Most whales leave these northern areas before the end of June (Benjaminsen 1972; Sigurjónsson and Gunnlaugsson 1990). Bottlenose whales are unlikely to occur north of Svalbard, and any animals that are present in the area are likely to leave before the *Healy* reaches the area in late September. Therefore, only a few, if any, bottlenose whales may be encountered during the proposed survey.

(e) Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan and globally fairly abundant. The killer whale is very common in temperate waters, but it also frequents tropical and polar waters. High densities of this species occur in high latitudes, especially in areas where prey is abundant. The greatest abundance is thought to occur within 800 km of major continents (Mitchell 1975). Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999).

Killer whales are known to inhabit almost all coastal waters of Alaska, extending from the Chukchi and Bering and Chukchi seas into the Beaufort Sea. The size of the Beaufort Sea population is not known but apparently very small; ~100 animals have been identified in the Bering Sea where the species is more common (ADFG 1994).

In the Atlantic, killer whales range across the North Atlantic from southern Greenland to Svalbard and south to Norway. They are not typically found north of Svalbard (Culik 2002). Christensen (1977) noted sightings of this species off the west coast of Norway. Øien (1990) noted killer whales off the Lofoten area; they occur in that area year-round, but are most abundant during the summer (Øien 1988 *in* Øien 1990). Killer whales have also been sighted off Møre, southern Norway (Stone 2003), where they are most abundant in February and March. Øien (1990) noted the mean group size as 14.67, with most pods (90.9%) consisting of 10 or fewer individuals and one sighting of a school of about 100 animals. Gunnlaugsson and Sigurjónsson (1990) gave an abundance estimate of 6618 animals for Icelandic, Faroese, and adjacent waters.

Although resident in some parts of their range, killer whales can also be transient. Killer whale movements generally appear to follow the distribution of prey. Killer whales are known to feed on herring aggregations in northern Norway (e.g., Simila and Ugarte 1993; Simila et al. 1996; Domenici et al. 2000), and Simila et al. (1996) noted that killer whales occurred in different areas during the summer and the fall-winter, coinciding with the distribution of herring. In the North Atlantic, killer whales are known to work in groups when hunting herring (Nottestad et al. 2002). They force the fish to the surface and split the large aggregation of fish into smaller schools, before attacking them (Nottestad et al. 2002). They also herd herring together at the surface and stun the fish by tail-slapping (Domenici et al. 2000).

The living generations of natives have never seen killer whales near Barrow, although their ancestors have seen killer whales. Killer whales are unlikely to be encountered during the proposed seismic survey.

(f) Long-finned Pilot Whale (*Globicephala melas*)

Long-finned pilot whales occur in mid-latitudes throughout the northern and southern hemisphere, including the temperate North Atlantic (Bernard and Reilly 1999); they are not found in the Beaufort Sea. There are an estimated 778,000 pilot whales in the eastern North Atlantic (Buckland et al. 1993). Although pilot whales occur in Norwegian waters, including waters near Svalbard, they are not found there in high abundance. In the North Atlantic, long-finned pilot whales are generally not found north of 80°N (Bernard and Reilly 1999). Catch records show that pilot whales are concentrated in two areas, primarily in July and August: Lofoten on the northwestern coast and Møre in southern Norway (Øien 1991). Skov et al. (1995) noted that the pilot whale was one of the most abundant cetaceans during surveys in the Northeast Atlantic. Pilot whales were sighted off southern Norway as well as around the Faroe Islands, but their distribution was rather patchy (Skov et al. 1995; Stone 2003).

Long-finned pilot whales are commonly seen around the Faroe Islands, within the archipelago as well as offshore (Abend and Smith 1999). They are hunted in this area (Bloch et al. 1989, 1993). A correlation has been established between the occurrence of pilot whales and surface water temperatures (Joensen and Zachariassen 1982; Bloch et al. 1989). In the Faroe Islands, as temperatures increase, prey availability also increases, especially of the European flying squid (*Todarodes saggitatus*), which is the preferred prey of the pilot whales (Desportes and Mouritsen 1993). Pilot whales are known to move to feeding grounds north of the islands when flying squid are not available (Desportes and Mouritsen 1993). Thus, their distribution changes on a seasonal basis in relation to the distribution of their prey (Payne and Heinemann 1993; Zachariassen 1993).

Pilot whales also occur regularly off the southern coast of Iceland; they do not occur along the northern coast (Abend and Smith 1999). The North Atlantic Current flows south of Iceland along the shelf edge towards Norway and likely influences pilot whale movements (Abend and Smith 1999). They prefer the shelf edge, only moving into shallower water occasionally (Abend and Smith 1999). They are most abundant in this area in mid-summer (Abend and Smith 1999).

Heide-Jørgensen et al. (2002) found that pilot whales outfitted with time-depth recorders dove to depths of up to 828 m, although most of their time was spent above 7 m. Pilot whales tagged near the Faroe Islands traveled average distances of 70–111 km over a 24 hr period; the maximum distance traveled in 24 hrs was 200 km (Bloch et al. 2003). The pilot whales traveled south and southwest of the Faroes as well as north and northeast; the most easterly transmission was obtained around 1ºE and the most northerly position was north of 64ºN (Bloch et al. 2003).

Pilot whales are very social and are usually seen in large groups 10 to 200 individuals (NAMMCO 2003a). Pods typically consist of related females and their offspring; adult females generally outnumber adult males in the groups (NAMMCO 2003a). Pods consisting of mainly males have also been observed (Desportes et al. 1992 *in* NAMMCO 2003a). Pilot whales are mainly pelagic and feed on squid as well as fish, such as mackerel (Reeves et al. 2002). In the North Atlantic, they mate and calve in April–September (Reeves et al. 2002).

Long-finned pilot whales are not generally found north of 80°N and so are not likely to be encountered during the active portion of the proposed cruise.

(g) Atlantic White-sided Dolphin (*Lagenorhynchus acutus*)

The white-sided dolphin occurs in temperate and subarctic waters of the North Atlantic, including continental shelves, slopes, and canyons (Reeves et al. 1999a); this species is not found in Alaskan waters.

White-sided dolphins sometimes occur on the west coast of Norway (Jonsgård 1952; Northbridge et al. 1997). Stone (2003) reported sightings of these dolphins in groups of 50 or more individuals off Møre, Norway. Øien (1996 *in* Reeves et al. 1999a) noted the occurrence of this species in the Barents Sea and southern Svalbard. White-sided dolphins have also been sighted near the Faroe Islands as well as south of Iceland (Skov et al. 1995).

During surveys in U.K. waters, white-sided dolphins were most abundant over deep water along the shelf edge (Weir et al. 2001). These dolphins were observed in that area during all months, but with large increases in numbers in August (Weir et al. 2001). Skov et al. (1995) noted that the white-sided dolphin was one of the most abundant cetacean species during surveys in the Northeast Atlantic, although they had a patchy distribution. This species is abundant in waters of 9–13ºC (Skov et al. 1995). White-sided dolphins have been seen in small groups, but commonly form larger pods of up to 1000 animals offshore.

Atlantic white-sided dolphins are not usually sighted north of Svalbard and are unlikely to be encountered by the proposed cruise.

(h) White-beaked Dolphin (*Lagenorhynchus albirostris*)

The white-beaked dolphin has a wide distribution in cold temperature and subarctic North Atlantic waters (Reeves et al. 1999b); this species is not found in Alaskan waters. The northern extent of this species is Svalbard, Norway (80ºN) (Reeves et al. 1999b). The white-beaked dolphin occurs along the coast of Norway and is likely the most common dolphin species in that region (Jonsgård 1962; Øien 1990; 1996 *in* Reeves et al. 1999b). Sightings of white-beaked dolphins have also been made off Møre, Norway (Stone 2003). White-beaked dolphins usually occur in groups of one to five individuals, with occasional groups of several hundred (Øien 1996 *in* Reeves et al. 1999b). They are primarily found in shelf waters (Reeves et al. 2002). Øien (1996 *in* Reeves et al. 1999b) estimated a total number of 132,000 delphinids (about 90% white-beaked dolphins) in the Barents Sea, eastern Norwegian Sea, and in the North Sea, north of 56ºN.

White-beaked dolphins are unlikely to be encountered north of Svalbard.

(i) Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is a small odontocete that inhabits shallow, coastal waters—temperate, subarctic, and arctic—in the Northern Hemisphere (Read 1999), including both the North Atlantic and the North Pacific. Harbor porpoises occur mainly in shelf areas (Read 1999). They dive to depths of at least 220 m and stay submerged for more than 5 min (Harwood and Wilson 2001). Harbor porpoises typically occur in small groups of only a few individuals (Read 1999). They feed on small, schooling fish (Read 1999) and tend to avoid vessels.

In the Northeast Atlantic, the subspecies *P. p. phocoena* is distributed from Novaya Zemlya in the Barents Sea down the coast of Europe, including Norway, as well as Iceland and the Faroe Islands (Rice 1998; Reid et al. 2003). Harbor porpoises have been sighted off the southern coast of Norway as well as around the Faroe Islands and during surveys in the Northeast Atlantic (Skov et al. 1995). Stone (2003) reported harbor porpoises off Møre, Norway, and north of the Shetland Islands. Øritsland et al. (1989) sighted harbor porpoises off northern Norway; their range touches upon southern Spitzbergen (Culik 2002).

The subspecies *P. p. vomerina* ranges from the Chukchi Sea, Pribilof Islands, Unimak Island, and the south-eastern shore of Bristol Bay south to San Luis Obispo Bay, California. Point Barrow, Alaska, is the approximate northeastern extent of their regular range (Suydam and George 1992), though there are extralimital records east to the mouth of the Mackenzie River in the Northwest Territories, Canada.

Given the harbor porpoise's vagrant status in the Beaufort Sea and the fact that Svalbard is at the northern limit of its usual range, plus the fact that it is mainly a shallow-water species, encounters with this species are highly unlikely in the Beaufort Sea and unlikely anywhere during the planned cruise.

(2) Mysticetes

(a) Bowhead Whale (*Balaena mysticetus*)

Bowhead whales only occur at high latitudes in the northern hemisphere and have a disjunct circumpolar distribution (Reeves 1980). They are one of only three whale species that spend their entire lives in the Arctic. Bowhead whales are found in the western Arctic (Bering, Chukchi, and Beaufort

Seas), the Canadian Arctic and West Greenland (Baffin Bay, Davis Strait, and Hudson Bay), the Okhotsk Sea (eastern Russia), and the Northeast Atlantic from Spitzbergen westward to eastern Greenland.

Bering–Chukchi–Beaufort stock: In Alaskan waters, bowhead whales winter in the central and western Bering Sea and summer in the Canadian Beaufort Sea (Moore and Reeves 1993). Spring migration through the Western Beaufort Sea occurs through offshore ice leads, generally from mid-April through mid-June (Braham et al. 1984; Moore and Reeves 1993).

Some bowheads arrive in coastal areas of the eastern Canadian Beaufort Sea and Amundsen Gulf in late May and June but most may remain among the offshore pack ice of the Beaufort Sea until mid summer. After feeding in the Canadian Beaufort Sea, bowheads migrate westward from late August through mid- or late October. Fall migration into Alaskan waters is primarily during September and October. However, in recent years a small number of bowheads have been seen or heard offshore from the Prudhoe Bay region during the last week of August (Treacy 1993; LGL and Greeneridge 1996; Greene 1997; Greene et al. 1999; Blackwell et al. 2004). Consistent with this, Nuiqsut whalers have stated that the earliest arriving bowheads have apparently reached the Cross Island area earlier in recent years than formerly (T. Napageak, pers. comm.).

The Minerals Management Service (MMS) has conducted or funded late-summer/autumn aerial surveys for bowhead whales in the Alaskan Beaufort Sea since 1979 (e.g., Ljungblad et al. 1986, 1987; Moore et al. 1989; Treacy 1988-1998, 2000, 2002a,b).

Bowheads tend to migrate west in deeper water (farther offshore) during years with higher-than-average ice coverage than in years with less ice (Moore 2000). In addition, the sighting rate tends to be lower in heavy ice years (Treacy 1997:67). During fall migration, most bowheads migrate west in water ranging from 15 to 200 m deep (Miller et al. 2002 *in* Richardson and Thomson 2002); some individuals enter shallower water, particularly in light ice years, but very few whales are ever seen shoreward of the barrier islands. Survey coverage far offshore in deep water is usually limited, and offshore movements may have been underestimated. However, the main migration corridor is over the continental shelf.

Bowhead whales typically reach the Barrow area during their westward migration from the feeding grounds in the Canadian Beaufort Sea in mid-September to late October. However, over the years, local residents report having seen a small number of bowhead whales feeding off Barrow or in the pack ice off Barrow during the summer. Autum bowhead whaling near Barrow normally begins in mid-September, but may begin as early as August if whales are observed and ice conditions are favorable (USDI/BLM 2005). Whaling can continue into October, depending on the quota and conditions.

The pre-exploitation population of bowhead whales in the Bering, Chukchi, and Beaufort seas is estimated to have been 10,400-23,000 whales, and that was reduced by commercial whaling to perhaps 3000 (Woodby and Botkin 1993). Up to the early 1990s, the population size was believed to be increasing at a rate of about 3.2% per year (Zeh et al. 1996; Angliss and Lodge 2002) despite annual subsistence harvests of 14–74 bowheads from 1973 to 1997 (Suydam et al. 1995). Allowing for an additional census in 2001, the latest estimates are an annual population growth rate of 3.4% (95% CI 1.7–5%) from 1978 to 2001 and a population size (in 2001) of ~10,470 animals (George et al. 2004). Assuming a continuing annual population growth of 3.4%, the 2005 bowhead population may number around 12,000 animals. The large increases in population estimates that occurred from the late 1970s to the early 1990s were partly a result of actual population growth, but were also partly attributable to improved census techniques (Zeh et al. 1993). Although apparently recovering well, the Bering–Chukchi–Beaufort bowhead population is currently listed as ***Endangered*** under the ESA and is classified as a strategic stock by the NMFS (Angliss and Lodge 2002).

Northeast Atlantic Stock: This population, whose range includes the Norwegian Sea, was heavily hunted around Svalbard commencing in the early 1600s (Allen and Keay 2004) and is now considered to be very close to extinction (Reeves 1980; Jonsgård 1981, 1982; McQuaid 1986; Zeh et al. 1993), if not extinct. Whaling records show that bowhead whales occurred in the Northeast Atlantic during spring, summer and autumn; wintering areas, however, were unknown (Christensen et al. 1992). Based on the winter habitat of other stocks, these bowhead whales likely overwintered in the pack ice in the Norwegian Sea (Moore and Reeves 1993).

Only a few observations of bowhead whales have been made in the Norwegian and Barents Sea in this century (e.g., Reeves 1980; Jonsgård 1981, 1982; McQuaid 1986; Clark and Brown 1991; Wiig 1991; Zeh et al. 1993). Christensen et al. (1992) reported additional sightings of single animals, including one animal seen near Jan Mayen in July 1992, one bowhead east of Iceland in 1967, and another bowhead in the Barents Sea in 1989.

Given the migratory patterns of bowhead whales in the western Beaufort Sea and results of other recent cruises (Harwood et al. 2005), it is considered unlikely that more than a few bowhead whales would be encountered near the beginning of the proposed cruise in early August. The need to be well away from the Alaskan coast before the main autumn migration period of bowheads was one consideration in selecting the early-August starting time for this cruise. Given the extreme rarity of sightings of bowhead whales of the Northeast Atlantic stock, it is unlikely that any will be encountered as the cruise approaches Svalbard. At the most only a few bowhead whales would be near the proposed trackline.

(b) North Atlantic Right Whale (*Eubalaena glacialis*)

North Atlantic right whales have been known to occur in the western and eastern North Atlantic from about 30º to 75ºN (Cummings 1985). Right whales spend the spring and summer at moderate and high latitudes, where they feed, and then migrate south for mating and calving in the winter (Cummings 1985). Historically, right whales occurred from Norway and Iceland to the British Isles, France, and Spain, but now they are very rare in these waters (Brown 1986; Harwood and Wilson 2001; Reeves et al. 2002; Reid et al. 2003). Whaling up until the early 20th century, including whaling in northwestern Europe (Reid et al. 2003), nearly extirpated the North Atlantic right whale (Reeves et al. 2002). The current population size of the North Atlantic right whale is estimated at about 300 animals, and most of these occur off the eastern United States and southeastern Canada (Reeves et al. 2002). However, a probable recent sighting of one individual was made north of the Shetland Islands (Stone 2003), and a sighting of a mother and calf was reported south of Greenland (Sigurjónsson et al. 1991). A right whale photoidentified off Massachusetts has recently been resighted off northern Norway and then resighted again off Massachusetts (Jacobsen et al. 2004).

The North Atlantic right whale population was severely depleted by whaling; its population remains very small and of much concern. It is listed as ***Endangered*** under the ESA and by IUCN, and is listed in Appendix 1 of CITES (Table 3). It is considered highly unlikely that any North Atlantic right whales would be encountered on the proposed survey route, particularly since the survey will terminate in late September above 80ºN and their normal autumn range is south of 60ºN.

(c) Gray Whale (*Eschrichtius robustus*)

Gray whales originally inhabited both the North Atlantic and North Pacific oceans. The Atlantic populations are believed to have become extinct by the early 1700s. There are two populations in the North Pacific. A relic population which survives in the Western Pacific summers near Sakhalin Island far from the proposed survey area. The larger eastern Pacific or California gray whale population recovered significantly from commercial whaling during its protection under the ESA until 1994 and numbered ~26,635 in 1998 (Rugh et al. 1999; Angliss and Lodge 2002; NMFS 2002). However, abundance estimates since 1998 indicate a consistent decline, and Rugh (2003 *in* Keller and Gerber 2004) estimated the population to be 17,500 in 2002. The eastern Pacific stock is not considered by NMFS to be a strategic stock.

Eastern Pacific gray whales breed and calve in the protected waters along the west coast of Baja California and the east coast of the Gulf of California from January to April (Swartz and Jones 1981; Jones and Swartz 1984). At the end of the breeding and calving season, most of these gray whales migrate about 8000 km, generally along the west coast, to the main summer feeding grounds in the northern Bering and Chukchi seas (Tomilin 1957; Rice and Wolman 1971; Braham 1984; Nerini 1984). However, no gray whales were sighted during cruises north of Barrow in 2002 (Harwood et al. 2005).

Most summering gray whales congregate in the northern Bering Sea, particularly off St. Lawrence Island and in the Chirikov Basin (Moore et al. 2000a), and in the southern Chukchi Sea. More recently, Moore et al. (2003) suggested that gray whale use of Chirikov Basin has decreased, likely as a result of the combined effects of changing currents resulting in altered secondary productivity dominated by lower quality food. The northeastern-most of the recurring feeding areas is in the northeastern Chukchi Sea southwest of Barrow (Clarke et al. 1989). Only a small number of gray whales enter the Beaufort Sea east of Point Barrow. Hunters at Cross Island (near Prudhoe Bay) took a single gray whale in 1933 (Maher 1960). Only one gray whale was sighted in the central Alaskan Beaufort Sea during the extensive aerial survey programs funded by MMS and industry from 1979 to 1997. However, during September 1998, small numbers of gray whales were sighted on several occasions in the central Alaskan Beaufort (Miller et al. 1999; Treacy 2000). More recently, a single sighting of a gray whale was made on 1 August 2001 near the Northstar production island (Williams and Coltrane 2002). Several single gray whales have been seen farther east in the Beaufort Sea (Rugh and Fraker 1981; LGL Ltd., unpubl. data), indicating that small numbers must travel through the region during some summers. In recent years, ice conditions have become lighter near Barrow, and gray whales may have become more common. In the springs of 2003 and 2004, a few tens of gray whales were seen near Barrow by early-to-mid June (LGL Ltd and NSB-DWM, unpubl. data).

Given the rare occurrence of gray whales in the Beaufort Sea in summer, no more than a few are expected to be in the region during the proposed activity. Those gray whales that are in the Beaufort Sea would be expected to remain close to shore and thus distant from most of the proposed activity. No gray whales are likely to be encountered after the first day or two of seismic operations, if then.

(d) Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a near-cosmopolitan distribution. The species is found in all major oceans and its range extends from the Bering Sea, north to Greenland and Svalbard, and south to Antarctic waters. Although this species is considered to be a mainly coastal species, it often traverses deep pelagic areas while migrating. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). The North Pacific population does not range north of the Bering Sea and will not be encountered during the proposed cruise. The North Atlantic population does extend far north into the Northeast Atlantic and a few individuals might be encountered near the terminus of the seismic survey.

During winter, the majority of the North Atlantic population breeds in the West Indies, but during the summer and fall, they occupy high-latitude feeding areas, including northern Norway (Smith et al.

1999). Stevick et al. (1998) reported a sighting of a humpback whale near Bear Island (off the northern coast of Norway) in July, and a resighting of the same whale in the West Indies in February, indicating a transit of at least 7815 km in seven months. Stevick et al. (1998) noted that the West Indies are used as a breeding and calving ground for whales that feed in Norwegian waters. Clark and Charif (1998) suggested a late-winter/early-spring southward migration of singing humpback whales in U.K. waters. Nonetheless, a small proportion of the humpback whale population remains in high latitudes in the eastern North Atlantic during winter (e.g., Christensen et al. 1992).

Øien (1990) noted that, in the Northeast Atlantic, humpback whales occurred mainly in the eastern part of the Norwegian Sea. Humpback whales have been sighted from May to July along the northern coast of Norway; near Lofoten, Spitzbergen, and near Bear Island (Christensen et al. 1992). In August, humpbacks are usually not observed along the northern coast of Finnmark, Norway (Christensen et al. 1992). There are few sightings for September and October, but most of those are in areas northeast of Hopen Island (near Spitzbergen; Christensen et al. 1992). The observations of whales in September and October are consistent with the general movement pattern to the north and east at the end of summer and in the autumn (Christensen et al. 1992). Stone (2003) reported sightings of humpback whales near the Faroe Islands and northeast of the Shetland Islands. Humpback whale distribution is likely related to the distribution of capelin; a collapse in the Barents Sea stock of capelin coincided with a lack of humpback whales near Finnmark and Hopen Island (e.g., Christensen et al. 1992).

Humpback whale densities, corrected for $f(0)$ but not $g(0)$, were estimated at 0.0039 whales per n.mi.^{2} for the Bear Island area, 0.0016 whales per n.mi.^{2} for the Kola coast, 0.0029 whales per n.mi.^{2} for the Lofoten area, and 0.0046 whales per n.mi.^{2} for the eastern part of the Norwegian Sea (Christensen et al. 1992). Average group size ranges between 1.4 and 2.1 (Christensen et al. 1992; Øien 1990); however, in their breeding and feeding ranges, they may occur in groups of up to 15 (Leatherwood and Reeves 1983). The abundance of humpback whales in the Norwegian and Barents seas is estimated at 700 animals by Christensen et al. (1992) and 1100 animals by Øien (1990). Gunnlaugsson and Sigurjónsson (1990) estimated a total of 1816 whales for Icelandic, Faroese, and adjacent waters.

Historically, humpback whales were hunted in Norwegian waters but they have not been hunted there in recent years. They are currently listed as ***Endangered*** under the ESA and IUCN, and in Appendix 1 of CITES (Table 3).

Although found in the waters around Svalbard, humpback whales are not commonly seen above 80ºN (ACS 2003b; Sea Around Us Project n.d.), and thus are unlikely to be encountered during the proposed cruise.

(e) Minke Whale (*Balaenoptera acutorostrata*)

Minke whales have a cosmopolitan distribution at ice-free latitudes (Stewart and Leatherwood 1985), and also occur in some marginal ice areas. In the North Pacific, minke whales range into the Bering and Chukchi seas but do not range into the Alaskan Beaufort Sea.

Minke whales are found throughout most of the North Atlantic, but generally occur in coastal and shelf areas (NAMMCO 2003b). For the Northeast Atlantic, the stock is estimated at 112,125 individuals (NAMMCO 1998). Gunnlaugsson and Sigurjónsson (1990) gave an abundance estimate of 41,131 minke whales for Icelandic, Faroese, and adjacent waters, with an estimated 904 animals in the proposed study area.

Stone (2003) noted the occurrence of minke whales off Møre, southern Norway. Christensen (1977) reported sightings of minke whales in northern Norway, Svalbard, and the Barents Sea. Øien

(1990) noted that minke whales in the northern part of Norway were concentrated around Jan Mayen, off the Kola coast, and between Bear Island and southwestern Spitzbergen. Minke whales have also been sighted round the Faroe Islands (Skov et al. 1995). Weir et al. (2001) noted that the minke whale was the most commonly sighted baleen whale during surveys in U.K. and adjacent waters in the Northeast Atlantic; most sightings occurred in water depths <200 m.

Minke whales tend to occur in higher latitudes in the summer and in lower latitudes in the winter (NAMMCO 2003b). Øien (1990) noted that group sizes range from 1 to 10 individuals, with a mean group size of 1.15. In the Northeast Atlantic, krill, herring and cod are the most important food items (NAMMCO 2003b). However, Haug et al. (1999) noted interannual variations in their diet, likely associated with prey availability.

A hunt for minke whales is conducted annually in Norwegian waters. In 2000 and 2001, 487 and 552 minke whales, respectively, were harvested in Norway (Statistics Norway 2002). In 2000, of the 487 minke whales taken, 228 were from the eastern Norwegian and Barents Seas, 16 from the Lofoten area, 57 from the Jan Mayen area, 103 from Svalbard/Bear Island, and 83 from the North Sea (NAMMCO 2001).

Minke whales do not typically range north of Svalbard (ACS 2003c; Sea Around Us Project n.d.) and are therefore unlikely to be encountered during the latter part of the proposed activity.

(f) Sei Whale (*Balaenoptera borealis*)

The sei whale has a near-cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). In the eastern Pacific, sei whales range into the Bering Sea, but they do not pass through the Bering Straits and are not found in the Alaskan Beaufort Sea. In the northeast Atlantic, sei whales are generally distributed south of 72ºN, although a few have been seen around 79ºN (Jonsgård 1966a). Cattanch et al. (1993) estimated sei whale abundance at 10,300 animals for Icelandic, Faroese and adjacent waters, with a total estimated abundance of 12–13,000 in the North Atlantic.

Sei whales were quite common along the western coast of Norway up to the late 1940s, but after 1960 few whales were seen, probably due to overexploitation (Jonsgård 1974). Sightings are made from time to time in the Norwegian Sea, including near Lofoten and Møre, Norway (Christensen et al. 1992; Stone 2003). Weir et al. (2001) noted the occurrence of sei whales to the south and southeast of the Faroe Islands and in the Faroe–Shetland Channel. Sei whales have occasionally been seen close to Svalbard.

Sei whales are thought to migrate between summer feeding areas at high latitudes and wintering areas at low latitudes (Jonsgård 1966a; Jonsgård and Darling 1977). The Northeast Atlantic population is thought to winter off Spain, Portugal, and northwest Africa (Harwood and Wilson 2001). The northward migration usually takes place in open waters off shore, and they arrive off the coast of Norway (off Møre) in April to May (Jonsgård and Darling 1977). Weir et al. (2001) noted that sei whales occur in the Northeast Atlantic from May to October, with peak numbers (28) having been sighted in August. Nonetheless, a small number of individuals have been sighted in the area between October and December, indicating that some animals may remain at higher latitudes during winter (Evans 1992). The sei whale is a pelagic species, and generally is not found in coastal waters (Harwood and Wilson 2001). This species usually occurs in small groups of up to six individuals.

Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The global population is thought to be low with current estimates at 54,000 animals (ACS 2003a). The sei whale is listed as ***Endangered*** under the ESA and by IUCN, and it is listed in CITES Appendix I (Table 3).

(g) Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985b), but typically occur in temperate and polar regions. The North Pacific population summers from the Chukchi Sea to California (Gambell 1985b) but does not range into the Alaskan Beaufort Sea. In the eastern North Atlantic, fin whales occur in winter from the Strait of Gibraltar to southwestern Norway, whereas in summer they range as far north as 80ºN (Harwood and Wilson 2001). Øien (1990) estimated the north Norway stock to be 1000 animals. Christensen et al. (1992) gave an estimate of 1906 animals for the north Norway stock, with another 339 individuals in the West Norway/Faroes stock. Gunnlaugsson and Sigurjónsson (1990) gave an abundance estimate of 7167 fin whales for Icelandic, Faroese, and adjacent waters, with an estimated of 281 animals in the proposed study area. The total population for the North Atlantic probably exceeds 46,000.

Fin whales have been sighted along the coast of Norway, especially near Lofoten, and along the Finnmark and Kola coasts, near Spitzbergen, east of the Faroe Islands, as well as off Møre (Christensen et al. 1992; Stone 2003). Densities of fin whales, corrected for $f(0)$ but not $g(0)$, range from 0.0186 whales per n.mi.^{2} in the area around Lofoten, to 0.0102 whales per n.mi.^{2} in the eastern part of the Norwegian Sea, to 0.0025 whales per n.mi.^{2} in the southern Norwegian Sea (Christensen et al. 1992). Øien (1990) noted that fin whales north of Norway tend to occur west of the slope between the Barents and Norwegian Seas. Otherwise, Øien (1990) reported densities in the Norwegian Sea to be low. The mean group size was noted as 1.83, with 51.5% of sightings being of single animals and 30.1% consisting of two whales (Øien 1990).

Fin whales feed in northern latitudes during the summer. Their prey includes plankton as well as shoaling pelagic fish, such as capelin *Mallotus villosus* (Jonsgård 1966a,b). The fin whale is listed as ***Endangered*** under the ESA and by IUCN, and it is a CITES Appendix I species (Table 3).

Since fin whales are rarely seen above 80ºN they are unlikely to be encountered during the latter part of the proposed cruise.

(h) Blue Whale (*Balaenoptera musculus*)

The blue whale is widely distributed throughout the world's oceans and occurs in coastal, shelf, and oceanic waters. The North Pacific population is estimated at 3500 animals (NMFS 1998) but does not range into the Beaufort Sea. In the Northeast Atlantic, its distribution extends from the Cape Verde Islands in the south to the pack ice (Jonsgård 1966a). Blue whales are thought to undergo a northward feeding migration in the spring and a return in autumn to breeding areas in the south (Jonsgård 1966a). Blue whales have been sighted in the southern part of the Norwegian Sea as well as east of Iceland (Christensen et al. 1992), in the Jan Mayen area, west of Lofoten on the northern coast of Norway, and west of Spitzbergen (Øritsland et al. 1989; Øien 1990; Christensen et al. 1992). Stone (2003) also noted a sighting offshore of Møre, Norway. These sightings indicate that at least a small number of blue whales summer in the area (Christensen et al. 1992).

Blue whale distribution, at least during times of the year when feeding is a major activity, is specific to areas that provide large seasonal concentrations of euphausiids (krill), which are the blue whale's main prey (Yochem and Leatherwood 1985). Blue whales are known to feed on krill in northern Norway. Blue whales may move back and forth between feeding grounds to follow plankton fronts along the continental shelf (Evans 1980).

Most blue whale stocks in the North Atlantic, including Norwegian and adjacent waters, were depleted during the 19th and first half of the 20th century (Jonsgård 1955) and are still low, including

Norwegian and adjacent waters. However, the stock that occurs in Icelandic and adjacent waters appears to have increased by 5% annually for the past 20 years (Sigurjónsson and Gunnlaugsson 1990). Blue whales in Icelandic waters number anywhere from 442 (Gunnlaugsson and Sigurjónsson 1990) to more than 1000 (Christensen et al. 1992) animals.

All populations of blue whales have been exploited commercially, and many have been severely depleted as a result. The blue whale is listed as ***Endangered*** under the ESA and by IUCN, and is listed in CITES Appendix I (Table 3).

Although the blue whale ranges from southern Greenland to southern Svalbard, it does not tend to range north of Svalbard and is typically not found above 80ºN (ACS 2003d; Sea Around Us Project n.d.). Thus, blue whales are unlikely to be encountered by the proposed cruise.

(3) Pinnipeds

(a) Pacific Walrus (*Odobenus rosmarus divergens*) and Atlantic Walrus (*O. r. rosmarus*)

Walruses occur in moving pack ice over shallow waters of the circumpolar Arctic coast (King 1983). There are two recognized subspecies of walrus. The Pacific walrus ranges from the Bering Sea to the Chukchi Sea, occasionally moving into the East Siberian and Beaufort seas, and the Atlantic walrus which is patchily distributed from the Canadian archipelago east into the Barents Sea and the Laptev Sea.

Walruses are migratory, moving south with the advancing ice in autumn and north as the ice recedes in spring (Fay 1981). In the summer, most of the population of the Pacific walrus moves to the Chukchi Sea, but several thousands aggregate in the Gulf of Anadyr and in Bristol Bay (Angliss and Lodge 2004). Limited numbers of walruses inhabit the Beaufort Sea during the open water season, and they are considered extralimital east of Point Barrow.

Estimates of the pre-exploitation population of the Pacific walrus range from 200,000 to 400,000 animals (USFWS 2000a). Over the past 150 years, the population has been depleted by over-harvesting and then periodically allowed to recover (Fay et al. 1989). The most current minimum population estimate is 188,316 walruses (USFWS 2000a). This estimate is conservative, because a portion of the Chukchi Sea was not surveyed due to lack of ice.

The northeast Chukchi Sea west of Barrow is the northeastern extend of the main summer range of the walrus, and only a few are seen farther east in the Beaufort Sea (e.g., Harwood et al. 2005). Walruses observed in the Beaufort Sea have typically been lone individuals. There were only five sightings of walruses between 146° and 150°W during MMS and LGL aerial surveys conducted from 1979 to 1995 (LGL and Greeneridge 1996). MMS surveys flown in the Beaufort Sea in fall 2000 (Treacy 2002a) and 2001 (Treacy 2002b) sighted no Pacific walruses, and there were no walrus sightings during marine mammal monitoring of open-water seismic exploration activities in the Prudhoe Bay area in 1997-2001 (Harris et al 1997, 1998; Moulton and Lawson 2001, 2002).

The reported subsistence harvest of walruses for Barrow for the 5-year period of 1994-1998 was 99 walruses (USDI 2000a). Most of these were harvested west of Point Barrow. In addition, between 1988 and 1998, Kaktovik harvested one walrus (USDI 2000b).

It is likely that the *Healy* will encounter few or no Pacific walruses as the seismic survey commences >40 km north of Barrow.

The Atlantic walrus population is estimated at 22,500 (SCS 2001), with ~6000 of those animals in Norwegian waters. Atlantic walruses are divided into eight sub-populations based on geographical distribution and movement data (NAMMCO 1995; Born et al. 2001). One of these sub-populations is found along Greenland's eastern coast while a second is located from Svalbard to Franz Joseph Land. The walrus population at Svalbard was nearly extirpated by overhunting (Wiig et al. 2000). Current population estimates are considered largely unreliable (Born et al. 1995; NAMMCO 1995), but are given as 500–1000 animals in eastern Greenland and <2000 animals in Svalbard-Franz Joseph Land. The Svalbard-Franz Joseph Land stock is believed to be increasing and has been completely protected from harvesting since 1952.

Atlantic walruses are typically found south of 81ºN (Norwegian Polar Institute 2003) which places the end of the proposed *Healy* route at the northernmost extent of their expected distribution. In light of this, it is likely that the *Healy* will encounter few, if any, Atlantic walruses while actively operating.

(b) Bearded Seal (*Erignathus barbatus*)

Bearded seals are associated with sea ice and have a circumpolar distribution (Burns 1981). During the open-water period, bearded seals occur mainly in relatively shallow areas, because they are predominantly benthic feeders (Burns 1981). They prefer areas of water no deeper than 200 m (e.g., Harwood et al. 2005).

In Alaskan waters, bearded seals occur over the continental shelves of the Bering, Chukchi, and Beaufort seas (Burns 1981). The Alaska stock of bearded seals may consist of about 300,000–450,000 individuals (MMS 1996). No reliable estimate of bearded seal abundance is available for the Beaufort Sea (Angliss and Lodge 2002). The Alaska stock of bearded seals is not classified by NMFS as a strategic stock.

The bearded seal is the largest of the northern phocids. Bearded seals have occasionally been reported to maintain breathing holes in the sea ice, and they occupy areas with pack ice. Bearded seals apparently also feed on ice-associated organisms when they are present, and this allows a few bearded seals to live in areas considerably deeper than 200 m.

Seasonal movements of bearded seals are directly related to the advance and retreat of sea ice and to water depth (Kelly 1988). During winter, most bearded seals in Alaskan waters are found in the Bering Sea. In the Chukchi and Beaufort seas, favorable conditions are more limited, and consequently, bearded seals are less abundant there during winter. From mid-April to June, as the ice recedes, some of the bearded seals that overwintered in the Bering Sea migrate northward through the Bering Strait. During the summer they are found near the widely fragmented margin of multi-year ice covering the continental shelf of the Chukchi Sea and in nearshore areas of the central and western Beaufort Sea. In the Beaufort Sea, bearded seals rarely use coastal haul-outs.

In some areas, bearded seals are associated with the ice year-round; however, they usually move shoreward into open water areas when the pack ice retreats to areas with water depths >200 m. During the summer, when the Bering Sea is ice-free, the most favorable bearded seal habitat is found in the central or northern Chukchi Sea along the margin of the pack ice. Suitable habitat is more limited in the Beaufort Sea where the continental shelf is narrower and the pack ice edge frequently occurs seaward of the shelf and over water too deep for benthic feeding. The preferred habitat in the western and central Beaufort Sea during the open water period is the continental shelf seaward of the scour zone.

Aerial surveys conducted by MMS in fall 2000 sighted a total of 35 bearded seals during survey flights conducted between 1 September and 19 October (Treacy 2002a). All but one of those sightings was made east of 147ºW and within 40 n.mi. of shore (Treacy 2002a). During surveys conducted by

MMS in fall 2001, 11 bearded seals were sighted (Treacy 2002b), with all but one of those sightings east of 147ºW and within 30 n.mi. of shore.

The proposed cruise is expected to encounter few bearded seals as it begins its cruise in the Beaufort Sea. The *Healy* will be in waters >200 m within 13 days of leaving Barrow and is unlikely to encounter bearded seals in subsequent days.

Bearded seals do have a circumpolar distribution and in some areas can be found as far north as 85ºN (mainly in the Canadian archipelago). In the northeast Atlantic, bearded seals are not typically found above 80ºN (SCS 2003; Reidman 1990), although they are widely distributed throughout Svalbard and the Barents Sea (Benjaminsen 1973). Bearded seals have been studied extensively near Svalbard in recent years (e.g., Hammill et al. 1994; Kovacs et al. 1996; Andersen et al. 1999; Hjelset et al. 1999; Krafft et al. 2000; Van Parijs et al. 2001, 2004).

The proposed cruise terminates its trackline above 80ºN and is thus unlikely to encounter many (if any) bearded seals during the latter portion of its trip.

(c) Harbor Seal (*Phoca vitulina*)

Harbor seals have a discontinuous range in the Pacific and Atlantic oceans (Bigg 1981). In the Pacific Ocean they range as far north as the southern Bering Sea, but do not enter the Chukchi or Beaufort seas and as such will not be encountered during the early portion of the proposed cruise.

There are an estimated 70,000 harbor seals in the eastern North Atlantic (Harwood and Wilson 2001) where they are usually called "common seals". In the Northeast Atlantic, they occur along the western European coast, including Norway (Thompson et al. 1998a). They are most abundant in southern Norway in the Ålesund–Bergen–Stavanger area, but are also found in Oslofjord (Øynes 1966 *in* King 1983). The population size of harbor seals in Norway is ~3800 (Reijnders et al. 1997 *in* Thompson et al. 1998a).

Harbor seals occur in coastal habitats. Along the Norwegian coast, harbor seals occur at open rocky coasts, deep fjords, and estuarine sandbanks (Bjørge 1991). The peak in pupping occurs in mid-June (Härkönen and Heide-Jørgensen 1990). Harbor seals forage inshore, usually <50 km from their haul-out sites (see review by Thompson 1993). However, Bjørge et al. (1995) showed that some seals forage 50–100 km from shore. There may be small, seasonal shifts in movement of 10–20 km between foraging areas visited during the breading season and those used during winter (Thompson 1989). Bjørge et al. (2002) found that harbor seals tagged on the Norwegian coast dispersed by a mean distance of 69 km; the maximum distance moved was 463 km. Adult harbor seals are relatively sedentary throughout the year, whereas subadults and pups show long range movements (Bonner and Witthames 1974).

A small colony of harbor seals is found in western Spitzbergen; this represents the northernmost occurrence of the species (Andersen et al. 2004), and seals tend to remain in the area all year. Henriksen et al. (1997) provided a population estimate of 500–600 animals on Svalbard and a total of 900–1000 for the Barents Sea.

Harbor seals are not expected to range north of Svalbard, and are therefore unlikely to be encountered during the latter part of the proposed cruise.

(d) Spotted Seal (*Phoca largha*)

Spotted seals (also known as largha seals) occur in the Beaufort, Chukchi, Bering and Okhotsk seas, and south to the northern Yellow Sea and western Sea of Japan (Shaughnessy and Fay 1977). They migrate south from the Chukchi Sea and through the Bering Sea in October (Lowry et al. 1998). Spotted seals overwinter in the Bering Sea and inhabit the southern margin of the ice during spring (Shaughnessy and Fay 1977).

An early estimate of the size of the world population of spotted seals was 370,000–420,000, and the size of the Bering Sea population, including animals in Russian waters, was estimated to be 200,000–250,000 animals (Bigg 1981). The total number of spotted seals in Alaskan waters is not known (Angliss and Lodge 2002), but the estimate is most likely between several thousand and several tens of thousands (Rugh et al. 1997). The Alaska stock of spotted seals is not classified as a strategic stock by NMFS (Hill and DeMaster 1998).

During spring when pupping, breeding, and molting occur, spotted seals are found along the southern edge of the sea ice in the Okhotsk and Bering seas (Quakenbush 1988; Rugh et al. 1997). In late April and early May, adult spotted seals are often seen on the ice in female-pup or male-female pairs, or in male-female-pup triads. Subadults may be seen in larger groups of up to two hundred animals. During the summer, spotted seals are found primarily in the Bering and Chukchi seas, but some range into the Beaufort Sea (Rugh et al. 1997; Lowry et al. 1998) from July until September. At this time of year, spotted seals haul out on land part of the time, but also spend extended periods at sea. The seals are commonly seen in bays, lagoons and estuaries, but also range far offshore as far north as 69–72ºN. In summer, they are rarely seen on the pack ice, except when the ice is very near to shore. As the ice cover thickens with the onset of winter, spotted seals leave the northern portions of their range and move into the Bering Sea (Lowry et al. 1998).

A small number of spotted seal haul-outs are (or were) located in the central Beaufort Sea in the deltas of the Colville River and, previously, the Sagavanirktok River. Historically, these sites supported as many as 400–600 spotted seals, but in recent times <20 seals have been seen at any one site (Johnson et al. 1999). In total, there are probably no more than a few tens of spotted seals along the coast of the central Alaska Beaufort Sea during summer and early fall. A total of 12 spotted seals were positively identified near the source vessel during open-water seismic programs in the central Alaskan Beaufort Sea during the six years from 1996 to 2001 (Moulton and Lawson 2002, p. 317). Numbers seen per year ranged from zero (in 1998 and 2000) to four (in 1999). No spotted seals were identified during MMS's fall 2000 and 2001 aerial surveys in the Beaufort Sea (Treacy 2002a,b).

The proposed cruise is expected to encounter few to no spotted seals during the first part of its trackline.

(e) Ringed Seal (*Pusa hispida*)

Ringed seals have a circumpolar distribution and occur in all seas of the Arctic Ocean (King 1983). They are closely associated with ice, and in the summer they often occur along the receding ice edges or farther north in the pack ice. In the North Pacific, they occur in the southern Bering Sea and range south to the seas of Okhotsk and Japan. They are found throughout the Beaufort, Chukchi, and Bering seas (Angliss and Lodge 2004).

Ringed seals are year-round residents in the Beaufort Sea and are the most frequently encountered seal species in the area. No estimate for the size of the Alaska ringed seal stock is currently available (Angliss and Lodge 2002). Past ringed seal population estimates in the Bering-Chukchi-Beaufort area ranged from 1–1.5 million (Frost 1985) to 3.3–3.6 million (Frost et al. 1988). Frost and Lowry (1981) estimated 80,000 ringed seals in the Beaufort Sea during summer and 40,000 during winter. More recent estimates based on extrapolation from aerial surveys and on predation estimates for polar bears (Amstrup

1995) estimate the Alaskan Beaufort Sea population at 326,500 animals. The Alaska stock of ringed seals is not classified as a strategic stock by the NMFS.

During winter, ringed seals occupy landfast ice and offshore pack ice of the Bering, Chukchi and Beaufort seas. In winter and spring, the highest densities of ringed seals are found on stable shorefast ice. However, in some areas where there is limited fast ice but wide expanses of pack ice, including the Beaufort Sea, Chukchi Sea and Baffin Bay, total numbers of ringed seals on pack ice may exceed those on shorefast ice (Burns 1970; Stirling et al. 1982; Finley et al. 1983). Ringed seals maintain breathing holes in the ice and occupy lairs in accumulated snow (Smith and Stirling 1975). They give birth in lairs from mid-March through April, nurse their pups in the lairs for 5–8 weeks, and mate in late April and May (Smith 1973; Hammill et al. 1991; Lydersen and Hammill 1993).

Frost et al. (2004) conducted aerial surveys of ringed seals along the central Beaufort Sea, between 149°50' and 143°42'W within 40 km of shore. Surveys were flown in 1996-1999 during late May and early June, when seals are most commonly hauled out on the ice. Based on their aerial survey counts, Frost et al. (2004) calculated ringed seal densities on fast ice to range from 0.57 to 1.14 seals/km^2. Observed densities ranged from 0.92 to 1.33 seals/km^2 on pack ice. Reported densities were not corrected for missed animals, i.e., for $f(0)$ or $g(0)$. Frost et al.'s densities do not differ greatly from other reported ringed seal densities in the high north. Stirling et al. (1977) reported densities of 0.1 to 0.5 seals/km^2 in the eastern Beaufort Sea during the 1970s and densities in northwestern Baffin Bay during the early 1980s ranged from 1.3 to 1.7 seals/km^2 (Finley et al. 1983).

During late May and early June 1997-1999, Moulton et al. (2002) surveyed ringed seals by plane along the Beaufort Sea from 147°06' to 149°04.5'W out to 37 m offshore. The Moulton et al. (2002) survey area is essentially a "subset" of Frost et al.'s (2004) surveyed area. The overall observed ringed seal densities on landfast ice ranged from 0.35 to 0.56 seals/km^2, significantly less than Frost et al.'s estimates. Their numbers are also not corrected for $f(0)$ or $g(0)$.

During summer, ringed seals are found dispersed throughout open water areas, although in some regions they move into coastal areas (Smith 1987; Harwood and Stirling 1992). During the open water period, ringed seals in the eastern Beaufort Sea are widely dispersed as single animals or small groups (Harwood and Stirling 1992). Marine mammal monitoring in the nearshore central Beaufort Sea confirms these generalities (Moulton and Lawson 2002; Williams et al. 2004). However, many groups consisting of more than five ringed seals were seen in September 1997 offshore from the Prudhoe Bay area (Harris et al. 1998).

In the North Atlantic, ringed seals occur almost everywhere where seasonal ice cover occurs (Reeves 1998). In the eastern Atlantic, ringed seals are found along the entire Eurasian Arctic coast, including Svalbard (NAMMCO 2003c) where the ringed seal is the most numerous seal found in the archipelago (Smith and Lydersen 1991). Ringed seals have been shown to move long distances (Kapel et al. 1998; Ridoux et al. 1998; Teilman et al. 1999), although they generally do not show seasonal migrations.

Ringed seals have been observed at or near 90ºN (Todd et al. 1992; van Meurs and Splettstoesser 2003). Ringed seals are likely to be the most commonly encountered marine mammal on all portions of the *Healy* cruise.

(f) Hooded Seal (*Cystophora cristata*)

Hooded seals are limited to arctic and subarctic North Atlantic waters (Reeves and Ling 1981); they are not found in the Beaufort Sea. In the eastern North Atlantic, the most important whelping area is in the pack ice ("West Ice") near Jan Mayen in the Greenland Sea (Reeves and Ling 1981). The population there numbers ~102,000 individuals (NAMMCO 2001). The global population of hooded seals is estimated at 300,000–600,000 animals (Kovaks and Lavigne 1986).

The hooded seal is a highly migratory species. Breeding occurs at the same time for each stock in February. Adults from all stocks then assemble in the Denmark Strait to molt between June and August (King 1983), and following this, the seals disperse widely. Some move south and west around the southern tip of Greenland, and then north along the west coast of Greenland. Others move to the east and north between Greenland and Svalbard during late summer and early fall (Lavigne and Kovacs 1988). Little else is known about the activities of hooded seals during the rest of the year until they assemble again in February for breeding. Hooded seal females pup in loose aggregations on the ice (Thompson et al. 1998a). Hooded seals are solitary animals and are found on drifting ice in offshore areas. They typically dive to depths of 100–600 m (Folkow and Blix 1995; Folkow et al. 1996) for 5–15 min.

Hooded seals are typically found south of 85ºN and thus are only likely to be encountered toward the end of the proposed cruise.

(g) Harp Seal (*Pagophilus groenlandicus*)

Harp seals occur in the northern Atlantic and Arctic Ocean (Ronald and Healy 1981). They occur in Svalbard and Jan Mayen, as well as along the northern coast of Norway (Ronald and Healy 1981). The Greenland Sea stock of harp seals, including the Jan Mayen area, numbers ~361,000 animals (NAMMCO 2001); the global population is estimated at 5.2 million animals (Healey and Stenson 2000). In the summer, they are located in more northerly latitudes, including Spitzbergen; however, those seals move south to Jan Mayen in the winter, where pupping occurs on the ice in March (King 1983). The molt occurs north of Jan Mayen in April (King 1983).

Harp seals eat a wide variety of food, the most important fish species including capelin, polar and Arctic cod, herring, sculpin, Greenland halibut, redfish and plaice. Also eaten are a large number of crustaceans such as amphipods, euphausiids (including krill), and decapods (including shrimps and prawns). Harp seals routinely dive to depths of 100 m while feeding. Known predators are polar bears, killer whales and sharks. Walruses also prey on harp seal females and pups in the White Sea.

Harp seal distribution is generally limited to below 84ºN (Reidman 1990) and as such, they are only likely to be encountered near the terminus of the proposed seismic operations.

(4) Carnivora

(a) Polar Bear (*Ursus maritimus*)

Polar bears have a circumpolar distribution throughout the northern hemisphere (Amstrup et al. 1986) and occur in relatively low densities throughout most ice-covered areas (DeMaster and Stirling 1981). Polar bears are divided into six major populations and many sub-populations based on mark-and-recapture studies (Lentfer 1983), radio telemetry studies (Amstrup and Gardner 1994), and morphometrics (Manning 1971; Wilson 1976). Polar bears are common in the Chukchi and Beaufort Seas north of Alaska throughout the year, including the late summer period (Harwood et al. 2005). They also occur throughout the East Siberian, Laptev, and Kara Seas of Russia and the Barent's Sea of northern Europe. They are found in the northern part of the Greenland Sea, and are common in Baffin Bay, which separates Canada and Greenland, as well as through most of the Canadian Arctic Archipelago.

Current world population estimates for the polar bear range from ~20,000 to 30,000 bears (Derocher et al. 1998). Amstrup (1995) estimated the minimum population of polar bears for the Beaufort Sea to be ~1500 to 1800 individuals, with an average density of about one bear per 38.6 to 77.2 square miles (100-200 km^2). There are no reliable data on the population status of polar bears in the Bering/Chukchi Sea; an estimate was derived by subtracting the total estimated Alaska polar bear population from the Beaufort Sea population, thus yielding an estimate of 1200–3200 animals (Amstrup 1995). The population near Svalbard is estimated at ~2000 animals (Polar Bears International 2004). In Norway, polar bears are classed as being Conservation Dependent.

The Alaskan polar bear population is considered to be stable or increasing slightly (USFWS 2000b,c). Polar bear populations located in the Southern Beaufort Sea have been estimated to have an annual growth rate of 2.2–2.4% with an annual harvest of only 1.9% (Amstrup 1995). Currently, neither stock is listed as "depleted" under the MMPA, or as "threatened" or "endangered" under the ESA (USFWS 2000b,c). Polar bear populations are protected under the MMPA of 1972, as well as by the International Agreement on the Conservation of Polar Bears, ratified in 1976. Countries participating in the latter treaty include: Canada, Denmark, Norway, Russia (former USSR), and the USA. Article II of the agreement states, "Each contracting party …shall manage polar bear populations in accordance with sound conservation practices based on the best scientific data."

The Southern Beaufort Sea population ranges from the Baillie Islands, Canada, in the east to Point Hope, Alaska, in the west. The Bering/Chukchi Sea population ranges from Point Barrow, Alaska in the east to the Eastern Siberian Sea in the west. These two populations overlap between Point Hope and Point Barrow, Alaska, centered near Point Lay (Amstrup 1995). Both of these populations have been extensively studied by tracking the movement of tagged females (Gardner et al. 1990). Radio-tracking studies indicate significant movement within populations and occasional movement between populations (Gardner et al. 1990; Amstrup 1995). For example, a female polar bear within sight of the Prudhoe Bay oilfields was captured, fitted with a satellite-tracking collar, and her movements monitored for 576 days. She traveled north and then south to Greenland, traversing ~7162 km in 576 days (Durner and Amstrup 1995). During fall 2000 (Treacy 2002a) aerial surveys, a total of 23 bears (in 9 sightings) were sighted in the Beaufort Sea, along with 28 sets of tracks. In fall 2001 (Treacy 2002b), 6 polar bears were observed in 4 sightings; 43 sets of tracks were also seen.

Polar bears usually forage in areas where there are high concentrations of ringed and bearded seals (Larsen 1985; Stirling and McEwan 1975). This includes areas of land-fast ice, as well as moving pack ice. Polar bears are opportunistic feeders and feed on a variety of foods and carcasses including not only seals but also beluga whales, arctic cod, geese and their eggs, walruses, bowhead whales, and reindeer (Smith 1985; Jefferson et al. 1993; Smith and Hill 1996; Derocher et al. 2000).

Females give birth to 1 to 3 cubs at an average interval of every 3.6 years (Jefferson et al. 1993; Lentfer et al. 1980). Cubs remain with their mothers for 1.4 to 3.4 years (Derocher et al. 1993; Ramsay and Stirling 1988). Mating occurs from April to June followed by a delayed implantation during September to December. Females give birth usually the following December or January (Harington 1968; Jefferson et al. 1993). In general, females 6 years of age or older successfully wean more young than younger bears; however, females as young as 4 years old can produce offspring (Ramsay and Stirling 1988). An examination of reproductive rates of polar bears indicated that 5% of four-year-old females had cubs, whereas 50% of five year-old females had cubs (Ramsay and Stirling 1988). Females that were over 20 years had a very high rate of cub loss or did not successfully reproduce. The maximum reproductive age reported for Alaskan polar bears is 18 years (Amstrup and DeMaster 1988).

Female polar bears usually enter maternity dens from late October through early November. These dens are excavated in accumulations of snow on land in coastal areas, on stable parts of offshore pack ice, or on land-fast ice. In a study of 90 radio-collared female polar bears conducted from 1981 to 1991 in the Beaufort Sea, 48 (53%) of the dens were located on pack ice, 38 (42%) were on land, and 4 (4%) were on land-fast ice (Amstrup and Gardner 1994).

Polar bears typically range as far north as 88°N (Ray 1971; Durner and Amstrup 1995), at about 88°N their population thins dramatically. However, polar bears have been observed across the Arctic, including close to the North Pole (van Meurs and Splettstoesser 2003). Stirling (1990) reported that of 181 sightings of bears, only three were above 82°N.

The *Healy* is likely to encounter polar bears when it enters the pack ice. Most encounters can be expected south of 82°N, although it is possible that small numbers of bears could be encountered anywhere along the entire trackline.

V. TYPE OF INCIDENTAL TAKE AUTHORIZATION REQUESTED

The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

UAF requests an IHA pursuant to Section 101 (a) (5) (D) of the MMPA for incidental take by harassment during its planned geophysical survey across the Arctic Ocean during August-September 2004.

The operations outlined in § I and II have the potential to take marine mammals by harassment. Sounds will mainly be generated by the airguns used during the survey, by a bathymetric sonar, a sub-bottom profiler sonar, pinger, and by general vessel operations. "Takes" by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airguns or sonars. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals in the general vicinity of the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, "MITIGATION MEASURES"). No lethal takes are expected.

VI. NUMBERS OF MARINE MAMMALS THAT MAY BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

VII. ANTICIPATED IMPACT ON SPECIES OR STOCKS

The anticipated impact of the activity upon the species or stock of marine mammal.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in Section VII. A more comprehensive review of the relevant background information appears in Appendix A.
- Then we discuss the potential impacts of operations by the bathymetric sonar, sub-bottom profiler, and pinger.
- Finally, we estimate the numbers of marine mammals that might be affected by the proposed activity in the Arctic Ocean in August-September 2004. This section includes a description of the rationale for the estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section VI.

(a) Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical effects (Richardson et al. 1995). Because the airgun sources planned for use during the present project involve only 1 or 2 airguns, the effects are anticipated to be considerably less than would be the case with a large array of airguns. It is very unlikely that there would be any cases of temporary or especially permanent hearing impairment, or non-auditory physical effects. Also, behavioral disturbance is expected to be limited to relatively short distances.

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix A (c). However, it should be noted that most of the measurements of airgun sounds that have been reported concerned sounds from larger arrays of airguns, whose sounds would be detectable considerably farther away than those planned for use in the present project.

Numerous studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix A (e). That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds, small odontocetes, and sea otters seem to be more tolerant of exposure to airgun pulses than are baleen whales. Given the low-energy airgun sources planned for use in this project, mammals are expected to tolerate being closer to these sources than would be the case for a larger airgun source typical of most seismic surveys.

Masking

Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data of relevance. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a more recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). That has also been shown during recent work in the Gulf of Mexico (Tyack et al. 2003). Given that the airgun sources planned for use here involve only 1 or 2 airguns, there is even less potential for masking of baleen or sperm whale calls during the present study than in most seismic surveys. Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses and the relatively low source level of the airgun configurations to be used here. Also, the sounds important to small odontocetes are predominantly at much higher frequencies than are airgun sounds. Masking effects, in general, are discussed further in Appendix A (d).

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Based on NMFS (2001, p. 9293), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. That likely overestimates the numbers of marine mammals that are affected in some biologically-important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray, and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, small toothed whales, and sea otters. Most of those studies have concerned reactions to much larger airgun sources than the airgun configurations planned for use in the present project. Thus, effects are expected to be limited to considerably smaller distances and shorter periods of exposure in the present project than in most of the previous work concerning marine mammal reactions to airguns.

Baleen Whales.— Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix A (e), baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the case of the migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses from large arrays of airguns diminish to those levels at distances ranging from 4.5 to 14.5 km from the source. A substantial proportion of the baleen whales within those distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies reviewed in Appendix A (e) have shown that some species of baleen whales, notably bowhead and humpback whales, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source [Miller et al. 1999; Richardson et al. 1999; see Appendix A (e)]. Reaction distances would be considerably smaller during the present project, as small energy sources will be used.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64 L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 μPa on an approximate rms basis. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa (~rms). More detailed information on responses of humpback whales to seismic pulses during studies in Australia can be found in Appendix A (a).

Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A *in* Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). Populations of both gray whales and bowhead whales grew substantially during this time. In any event, the brief exposures to sound pulses from the proposed small airgun sources are highly unlikely to result in prolonged effects.

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above and in Appendix A have been reported for toothed whales. However, systematic work on sperm whales is underway (Tyack et al. 2003), and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies (e.g., Stone 2003; Smultea et al. 2004).

Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of seismic vessels operating large airgun systems. However, some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when large arrays of airguns are firing. Nonetheless, there have been indications that small toothed whales sometimes move away, or maintain a somewhat greater distance from the vessel, when a large array of airguns is operating than when it is silent (e.g., Goold 1996; Calambokidis and Osmek 1998; Stone 2003). Similarly, captive bottlenose dolphins and (of some relevance in this project) beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 μPa) before exhibiting aversive behaviors. Given that the presently-planned airgun sources involve only 1 or 2 airguns, such levels would only be found within a few tens of meters of the airgun(s).

There are no specific data on the behavioral reactions of beaked whales to seismic surveys. A few beaked whale sightings have been reported from seismic vessels (Stone 2003). However, most beaked whales tend to avoid approaching vessels even without the added noise from airguns (e.g., Kasuya 1986; Würsig et al. 1998). There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operations, are ongoing nearby—see Appendix A (g). The strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below). Given the equivocal (at most) evidence of beaked whale strandings in response to operations with large arrays of airguns, and the lack of beaked whales along most of the planned route, strandings in response to the 1 or 2 airguns to be used for this survey are very unlikely.

Sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds, and it is to be expected that they would tend to avoid an operating seismic survey vessel. There were some limited early observations suggesting that sperm whales in the Southern Ocean and Gulf of Mexico might be fairly sensitive to airgun sounds from distant seismic surveys. However, more extensive data from recent studies in the North Atlantic (including northern Norway) suggest that sperm whales in those areas show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (McCall Howard 1999; Madsen et al. 2002; Stone 2003). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico has been done recently (Tyack et al. 2002 *in* Jochens and Biggs 2003). That study has shown little evidence of responses to received sound levels up to ≥140 dB re 1 μPa (rms) despite use of innovative observation methods that provide unusually detailed documentation of foraging and acoustic behavior during exposure to airgun sounds.

Odontocete reactions to large arrays of airguns are variable and, at least for small odontocetes, seem to be confined to a smaller radius than has been observed for mysticetes. Thus, behavioral reactions of odontocetes to the low-energy sources to be used here are expected to be very localized.

Pinnipeds.— Pinnipeds are not likely to show a strong avoidance reaction to the small airgun sources that will be used. Visual monitoring from seismic vessels, usually employing larger sources, has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix A (e). Those studies show that pinnipeds frequently do not avoid the area within a few hundred meters of operating airgun arrays, even for arrays considerably larger than the airgun sources to be used here (e.g., Harris et al. 2001). However, initial telemetry work suggests that avoidance and other behavioral reactions to small airgun sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al. 1998b). Even if reactions of the species occurring in the present study area are as strong as those evident in the telemetry study, reactions are expected to be confined to relatively small distances and durations, with no long-term effects on pinniped individuals or populations.

Polar Bears.— Airgun effects on polar bears have not been studied. However, polar bears on the ice would be unaffected by underwater sound. Sound levels received by polar bears in the water would be attenuated because polar bears generally do not dive much below the surface. Received levels of airgun sounds are reduced near the surface because of the pressure release effect at the water's surface (Greene and Richardson 1988; Richardson et al. 1995).

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix A.

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this for marine mammals exposed to sequences of airgun pulses. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (=shut-down) radii planned for the proposed seismic survey. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause temporary auditory impairment in marine mammals. As discussed in Appendix A (f) and summarized here,

- the 180-dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary threshold shift (TTS), let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

NMFS is presently developing new noise exposure criteria for marine mammals that take account of the now-available data on TTS and other relevant factors in marine and terrestrial mammals (NMFS 2005; D. Wieting *in* http://mmc.gov/sound/plenary2/pdf/plenary2summaryfinal.pdf).

Because the airgun sources planned for use during this project involve only 1 or 2 guns, and with the planned monitoring and mitigation measures, there is little likelihood that any marine mammals will be exposed to sounds sufficiently strong to cause even the mildest (and reversible) form of hearing impairment. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun(s), and multi-beam sonar, and to avoid exposing them to sound pulses that might (at least in theory) cause hearing impairment [see § XI, "MITIGATION MEASURES"]. In addition, many cetaceans are likely to show some avoidance of the small area with high received levels of airgun sound (see above). In those cases, the avoidance responses of the animals themselves will reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects might also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. However, as discussed below, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. It is especially unlikely that any effects of these types would occur during the present project given the small size of the source, the brief duration of exposure of any given mammal, and the planned monitoring and mitigation measures (see below). The following subsections discuss in somewhat more detail the possibilities of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).— TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002). Given the available data, the received level of a single seismic pulse might need to be ~210 dB re 1 μPa rms (~221–226 dB pk–pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m around a seismic vessel operating a large array of airguns. Such levels would be limited to distances within a few meters of the low-energy airgun sources to be used in this project.

For baleen whales, there are no data, direct or indirect, on levels or properties of sound that are required to induce TTS. However, no cases of TTS are expected given that the airgun sources involve only 1 or 2 airguns, and the strong likelihood that baleen whales would avoid the approaching airgun(s), or vessel, before being exposed to levels high enough for there to be any possibility of TTS.

In pinnipeds, TTS thresholds associated with exposure to brief pulses (single or multiple) of underwater sound have not been measured. Initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999; Ketten et al. 2001; *cf*. Au et al. 2000). However, more recent indications are that TTS onset in the most sensitive pinniped species studied (harbor seal) may occur at a similar sound exposure level as in odontocetes (Kastak et al. 2004).

A marine mammal within a radius of ≤100 m (≤328 ft) around a typical large array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel. (As noted above, most cetacean species tend to avoid operating airguns, although not all individuals do so.) However, several of the considerations that are relevant in assessing the impact of typical seismic surveys with arrays of airguns are not directly applicable here:

- The planned airgun sources involve only 1 or 2 airguns, with correspondingly smaller radii within which received sound levels could exceed any particular level of concern (Table 2).
- "Ramping up" (soft start) is standard operational protocol during startup of large airgun arrays in many jurisdictions. Ramping up involves starting the airguns in sequence, usually commencing with a single airgun and gradually adding additional airguns. This practice will be employed when the 2 G. guns are operated.
- Even with a large airgun array, it is unlikely that cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. In this project, the airgun sources are much less strong, so the radius of influence and duration of exposure to strong pulses is much smaller, especially in deep and intermediate-depth water.
- With a large array of airguns, TTS would be most likely in any odontocetes that bow-ride or otherwise linger near the airguns. In the present project, the anticipated 180 dB distances in deep and intermediate-depth water are 325 and 500 m, respectively, for the 2 G. gun system, and 50 and

75 m, respectively, for the single Bolt airgun (Table 2). The waterline at the bow of the *Healy* will be ~123 m ahead of the airgun.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 µPa (rms). The 180 and 190 dB distances for the airguns operated by UAF vary with water depth. They are estimated to be 325 m and 100 m, respectively, in deep water for the 2 G. gun system, but are predicted to increase to 2400 m and 1500 m, respectively, in shallow water (Table 2). The 180 and 190 dB distances for the single Bolt airgun are 50 and 25 m, respectively, in deep water but 370 and 313 m in shallow water. Shallow water (<100 m) will occur along only 48 km (~1 %) of the planned trackline. Furthermore, those sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, TTS data that are now available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses much stronger than 180 dB re 1 µPa rms.

Permanent Threshold Shift (PTS).—When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, whereas in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that mammals close to an airgun array might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals, but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level 20 dB or more above that inducing mild TTS if the animal were exposed to the strong sound for an extended period, or to a strong sound with very rapid rise time—see Appendix A (f).

It is highly unlikely that marine mammals could receive sounds strong enough (and over a sufficient duration) to cause permanent hearing impairment during a project employing only 1 or 2 airguns as planned here. In the proposed project, marine mammals are unlikely to be exposed to received levels of seismic pulses strong enough to cause TTS, as they would probably need to be within several meters of the airgun for that to occur. Given the higher level of sound necessary to cause PTS, it is even less likely that PTS could occur. In fact, even the levels immediately adjacent to the airgun may not be sufficient to induce PTS, especially because a mammal would not be exposed to more than one strong pulse unless it swam immediately alongside the airgun for a period longer than the inter-pulse interval. Baleen whales generally avoid the immediate area around operating seismic vessels. The planned monitoring and mitigation measures, including visual monitoring power downs and shut downs of the airguns when mammals are seen within the "safety radii", will minimize the already-minimal probability of exposure of marine mammals to sounds strong enough to induce PTS.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays (even large ones). However, there have been no direct studies of the potential for airgun pulses to elicit any of those effects.

If any such effects do occur, they probably would be limited to unusual situations when animals might be exposed at close range for unusually long periods.

It is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. That is especially so in the case of the present project which will deploy only 1 or 2 airguns, the ship is moving 3–4 knots, and for the most part the tracklines will not “double back” through the same area.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at that frequency, the ensuing resonance could cause damage to the animal. A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused the stranding. Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolisms. However, a recent article documents the probability of the bends manifested in sperm whale skeletons (Moore and Early 2004). Skeletal pitting and erosion, hypothesized to be the result of nitrogen emboli, was discovered in 16 sperm whale skeletons spanning a period of 111 years. Larger sperm whale skeletons exhibited the most damage, indicating a chronic pathology. Another short paper concerning beaked whales stranded in the Canary Islands in 2002 suggests that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, that might occur if they ascend unusually quickly when exposed to aversive sounds. However, the interpretation that the effect was related to decompression injury is unproven (Piantadosi and Thalmann 2004; Fernández et al. 2004). Even if that effect can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to airgun sounds. It is especially unlikely in the case of the proposed survey, involving only 1 or 2 airguns that will operate in any one location only briefly.

In general, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances and probably to projects involving large arrays of airguns. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in those ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur auditory impairment or other physical effects. Also, the planned monitoring and mitigation measures include shut downs of the airguns, which will reduce any such effects that might otherwise occur.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding even in the case of large airgun arrays. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding. Appendix A (g) provides additional details.

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2–10 kHz, generally with a relatively narrow bandwidth at any one time. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to physical damage and mortality (NOAA and USN 2001; Jepson et al. 2003), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

In May 1996, 12 Cuvier's beaked whales stranded along the coasts of Kyparissiakos Gulf in the Mediterranean Sea. That stranding was subsequently linked to the use of low- and medium-frequency active sonar by a North Atlantic Treaty Organization (NATO) research vessel in the region (Frantzis 1998). In March 2000, a population of Cuvier's beaked whales being studied in the Bahamas disappeared after a U.S. Navy task force using mid-frequency tactical sonars passed through the area; some beaked whales stranded (Balcomb and Claridge 2001; NOAA and USN 2001).

In September 2002, a total of 14 beaked whales of various species stranded coincident with naval exercises in the Canary Islands (Martel n.d.; Jepson et al. 2003; Fernández et al. 2003). Also in Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel *Maurice Ewing* was operating a 20-airgun, 8490 in^3 array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, that plus the incidents involving beaked whale strandings near naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

The present project will involve lower-energy sound sources than used in typical seismic surveys. That, along with the monitoring and mitigation measures that are planned, and the infrequent occurrence of beaked whales in the project area, will minimize any possibility for strandings and mortality.

(b) Possible Effects of Bathymetric Sonar Signals

A SeaBeam 2112 multi-beam 12 kHz bathymetric sonar system will be operated from the source vessel essentially continuously during the planned study. Details about the SeaBeam 2112 were provided in Section I. Sounds from the multi-beam are very short pulses, depending on water depth. Most of the energy in the sound pulses emitted by the multi-beam is at moderately high frequencies, centered at 12 kHz. The beam is narrow (~2°) in fore-aft extent and wide (~130º) in the cross-track extent. Any given mammal at depth near the trackline would be in the main beam for only a fraction of a second.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the SeaBeam 2112 sonar, (2) have a longer pulse duration, and (3) are directed close to horizontally vs. downward for the SeaBeam 2112. The area of possible influence of the bathymetric sonar is much smaller—a narrow band oriented in the cross-track direction below the source vessel. Marine mammals that encounter the bathymetric sonar at close range are unlikely to be subjected to repeated pulses because of the narrow fore-aft width of the beam, and will receive only small amounts of pulse energy because of the short pulses. In assessing the possible impacts of a 15.5 kHz Atlas Hydrosweep multi-beam bathymetric sonar, Boebel et al. (2004) noted that the critical sound pressure level at which TTS may occur is 203.2 dB re 1 µPa (rms). The critical region included an area of 43 m in depth, 46 m wide athwartship, and 1 m fore-and-aft (Boebel et al. 2004). In the more distant parts of that (small) critical region, only slight TTS would be incurred.

Masking

Marine mammal communications will not be masked appreciably by the bathymetric sonar signals given the low duty cycle of the sonar and the brief period when an individual mammal is likely to be within the sonar beam. Furthermore, the 12 kHz multi-beam will not overlap with the predominant frequencies in baleen whale calls, further reducing any potential for masking in that group.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to military and other sonars appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. Also, Navy personnel have described observations of dolphins bow-riding adjacent to bow-mounted mid-frequency sonars during sonar transmissions. However, all of those observations are of limited relevance to the present situation. Pulse durations from those sonars were much longer than those of the bathymetric sonars to be used during the proposed study, and a given mammal would have received many pulses from the naval sonars. During UAF's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies similar to those that will be emitted by the bathymetric sonar to be used by UAF, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002). The relevance of those data to free-ranging odontocetes is uncertain, and in any case, the test sounds were quite different in either duration or bandwidth as compared with those from a bathymetric sonar.

We are not aware of any data on the reactions of pinnipeds to sonar sounds at frequencies similar to those of the multi-beam sonar (12 kHz). Based on observed pinniped responses to other types of pulsed sounds, and the likely brevity of exposure to the bathymetric sonar sounds, pinniped reactions to the sonar sounds are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

Polar bears would not occur below the *Healy* or elsewhere at sufficient depth to be in the main beam of the bathymetric sonar, so would not be affected by the sonar sounds.

As noted earlier, NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans or pinnipeds to small numbers of signals from a multi-beam bathymetric sonar system would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the multi-beam sonar proposed for use by UAF is quite different from sonars used for navy operations. Pulse duration of the bathymetric sonar is very short relative to the naval sonars. Also, at any given location, an individual cetacean or pinniped would be in the beam of the multi-beam sonar for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth. (Navy sonars often use near-horizontally-directed sound.) Those factors would all reduce the sound energy received from the bathymetric sonar relative to that from the sonars used by the Navy. Polar bears would not occur in the main beam of the sonar.

(c) Possible Effects of Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel most times during the planned survey. Details about the equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses; pulse duration ranges from 0.5 to 25 milliseconds, and the interval between pulses can range between 0.25 s and 10 s, depending upon water depth. A 3.5 kHz transducer emits a conical beam with a width of 26° and the 12 kHz transducer emits a conical beam with a width of 30°. The swept (chirp) frequency ranges from 2.75 kHz to 6 kHz. Most if the energy from the sub-bottom profiler is directed downward from the transducer array.

Sound levels have not been measured directly for the sub-bottom profiler used by the *Healy*, but Burgess and Lawson (2000) measured sounds propagating more or less horizontally from a similar unit with similar source output (205 dB re 1 μPa·m). The 160 and 180 dB re 1 μPa rms radii, in the horizontal direction, were estimated to be, respectively, near 20 m (66 ft) and 8 m (26 ft) from the source, as measured in 13 m or 43 ft water depth. The corresponding distances for an animal in the beam below the transducer would be greater, on the order of 180 m (591 ft) and 18 m (59 ft), assuming spherical spreading.

Masking

Marine mammal communications will not be masked appreciably by the sub-bottom profiler signals given its relatively low power output, the low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the sub-bottom profiler are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profiler are much weaker than those from the airgun(s) and the multi-beam sonar. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans to small numbers of signals from the sub-bottom profiler would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Source levels of the sub-bottom profiler are much lower than those of the airguns and the multi-beam sonar, which are discussed above. Sound levels from a sub-bottom profiler similar to the one on the *Healy* were estimated to decrease to 180 dB re 1 μPa (rms) at 8 m horizontally from the source (Burgess and Lawson 2000), and at ~18 m downward from the source. Furthermore, received levels of pulsed sounds that are necessary to cause temporary or especially permanent hearing impairment in marine mammals appear to be higher than 180 dB (see earlier). Thus, it is unlikely that the sub-bottom profiler produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source.

The sub-bottom profiler is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources or the vessel itself before the mammals would be close enough for there to be any possibility of effects from the less intense sounds from the sub-bottom profiler. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of the higher-power sources (see § XI) would further reduce or eliminate any minor effects of the sub-bottom profiler. Given the brevity of the pulses from each source [sub-bottom profiler, multi-beam sonar, airgun(s)], and the directionality of the first two sources, it would be rare for an animal to receive pulses from 2 or 3 of the sources simultaneously. In the unlikely event that simultaneous reception did occur, the combined received level would be little different from that attributable to the strongest single source (see eq'n 2.9 *in* Richardson et al. 1995, p. 30).

(d) Possible Effects of Pinger Signals

A pinger will be operated during all coring, to monitor the depth of the core relative to the sea floor. Sounds from the pinger are very short pulses, occurring for 0.5, 2 or 10 ms once every second, with source level ~192 dB re 1 μPa-m at a one pulse per second rate. Most of the energy in the sound pulses emitted by this pinger is at mid frequencies, centered at 12 kHz. The signal is omnidirectional. The pinger produces sounds that are within the range of frequencies used by small odontocetes and pinnipeds that occur or may occur in the area of the planned survey.

Masking

Whereas the pinger produces sounds within the frequency range used by odontocetes that may be present in the survey area and within the frequency range heard by pinnipeds, marine mammal communications will not be masked appreciably by the pinger signals. This is a consequence of the relatively low power output, low duty cycle, and brief period when an individual mammal is likely to be within the area of potential effects. In the case of mysticetes, the pulses do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the pinger are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the pinger are much weaker than those from the bathymetric sonars and from the airgun. Therefore, behavioral responses are not expected unless marine mammals are very close to the source.

NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". The vessel will be nearly stationary during coring, so marine mammals could be exposed to signals from the pinger for longer periods than while the vessel is underway. However, even that length of exposure would not result in a "take" by harassment because of the strength of the signal.

Hearing Impairment and Other Physical Effects

Source levels of the pinger are much lower than those of the airguns and bathymetric sonars, which are discussed above. It is unlikely that the pinger produces pulse levels strong enough to cause temporary hearing impairment or (especially) physical injuries even in an animal that is (briefly) in a position near the source.

(e) Numbers of Marine Mammals that Might be "Taken by Harassment"

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix A, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate "take by harassment" and present estimates of the numbers of marine mammals that might be affected during the proposed seismic study across the Arctic Ocean. The estimates are based on data obtained during marine mammal surveys in and near the Arctic Ocean by Stirling et al. (1982), Kingsley (1986), Christensen et al. (1992), Koski and Davis (1994), Moore et al. (2000a), Whitehead (2002), and Moulton and Williams (2003), and on estimates of the sizes of the areas where effects could potentially occur.

This section provides estimates of the number of potential "exposures" to sound levels ≥160 and/or ≥170 dB re 1 µPa (rms). The ≥160 dB criterion is applied for all species of cetaceans and pinnipeds; the ≥170 dB criterion is applied for delphinids and pinnipeds. The 170 dB criterion is considered appropriate for those two groups, which tend to be less responsive, whereas the 160 dB criterion is considered appropriate for other cetaceans.

Although several systematic surveys of marine mammals have been conducted in the southern Beaufort Sea and northern Atlantic Ocean, few data (systematic or otherwise) are available on the numbers and distributions of marine mammals through the central Arctic Ocean. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection. There is some uncertainty about the representativeness of those data and the assumptions used below to estimate the potential "take by harassment", especially as applied to the central part of the study area. However, the approach used here seems to be the best available approach.

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by ~4060 line kilometers of seismic surveys across the Arctic Ocean: 2801 line kilometers with the two 250 in^3 G. guns and 1258 line kilometers with a single Bolt 1200 in^3 airgun. An assumed total of 5075 km of trackline includes a 25% allowance over and above the planned ~4060 km to allow for turns, lines that might have to be repeated because of poor data quality, or for minor changes to the survey design.

The anticipated radii of influence of the bathymetric sonars and pinger are less than those for the airgun configurations. It is assumed that, during simultaneous operations of those additional sound sources and the airgun(s), any marine mammals close enough to be affected by the sonars or pinger would already be affected by the airgun(s). However, whether or not the airgun(s) is operating simultaneously with the sonar or pinger, marine mammals are expected to exhibit no more than short-term and inconsequential responses to the sonars or pinger given their characteristics (e.g., narrow downward-directed beam) and other considerations described in § I and VII. Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by the sound sources other than the airgun(s).

Basis for Estimating "Take by Harassment"

Numbers of marine mammals that might be present and potentially disturbed are estimated below based on available data about mammal distribution and densities in the area. The main sources of numerical information about numbers and densities of marine mammals in the area are summarized here.

Cetaceans

Although surveys of marine mammals have been conducted near the start and end of the planned transit, few data are available on the species and distributions of marine mammals in the central Arctic Ocean, and no data are available on the densities of marine mammals there.

The best data are from surveys in the Beaufort Sea. Moore et al. (2000a) report densities of belugas, bowheads and gray whales during summer in the Beaufort and Chukchi seas, but their densities overestimate densities within the proposed seismic survey area because most bowheads and belugas are east of the proposed seismic area and most gray whales are southwest of it. Kingsley (1986) reported the density of ringed seals on the offshore pack ice in the central Beaufort Sea, but that density probably overestimates the density in far offshore waters where densities of ringed seals are believed to be lower than nearer to the coast. Densities of polar bears were estimated from data collected during ringed seal surveys along landfast ice in the west-central Beaufort Sea (Moulton and Williams 2003). It is not known whether these densities are representative of densities on the offshore pack ice, particularly during late summer. In recent years, many polar bears have concentrated near bowhead butchering sites on land during late summer.

No systematic survey data are available for the pack ice north of Svalbard, but surveys of adjacent areas in the northeast Atlantic have been conducted by Christensen et al. (1992) and narwhal surveys were conducted in Scoresby Sound by Larsen et al. (1994).

As noted above, there is some uncertainty about the representativeness of the data and assumptions used in the calculations. Because no quantitative data were available for the central Arctic Ocean, we arbitrarily assigned densities based on densities observed in adjacent areas of the Beaufort Sea or northeast Atlantic Ocean. It is not known how closely the densities that were used reflect the actual densities that will be encountered; however, the approach used here is believed to be the best available approach. To provide some allowance for the uncertainties, "maximum estimates" as well as "best estimates" of the numbers potentially affected have been derived. For a few marine mammal species, several density estimates were available, and in those cases, the mean and maximum estimates were from the survey data. For those species where only one density estimate was available, the "maximum density" was usually assumed to be 4× the mean density. When the seismic survey area is on the edge of the range of a species, we used the available mammal survey data as the maximum estimate and assumed that the average density along the seismic trackline will be ~0.25× the density from the available survey data. The assumed densities are believed to be similar to, or in most cases higher than, the densities that will be encountered during the survey.

Table 4 gives the average and maximum densities for each cetacean species or species group reported to occur in the Arctic Ocean north of Barrow and south of 78° N, based on the sightings and effort data from the above reports. Only ~1% of the planned survey will be conducted in water depths <100 m, and so the densities in the table are based on surveys of offshore waters. The densities calculated from sightings during the studies have been adjusted (where needed) using correction factors from Koski et al. (1998) and Barlow (1999), for both detectability and availability biases. Detectability bias, quantified in part by $f(0)$, is associated with diminishing sightability with increasing lateral distance from the trackline. Availability bias, $g(0)$, refers to the fact that there is <100% probability of sighting an animal that is present along the survey trackline.

Table 5 gives the average and maximum densities that are estimated to occur in the consolidated polar pack ice between 78°N, far north of Barrow, and 82.2°N, north of Svalbard. Table 6 gives the same data for the polar pack north of Svalbard but south of 82.2°N.

TABLE 4. Expected densities of marine mammals in offshore areas of the Beaufort and Chukchi seas, **near Barrow, Alaska**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed as endangered are in italics.

Species	Average Density [a] (# / km^2)	Maximum Density (# / km^2)
Odontocetes		
Sperm whale	*0.0000*	*0.0000*
Ziphiidae		
Northern bottlenose whale	0.0000	0.0000
Monodontidae		
Beluga [b]	0.0034	0.0135
Narwhal [f]	0.0000	0.0001
Delphinidae		
Atlantic white-beaked dolphin	0.0000	0.0000
Atlantic white-sided dolphin	0.0000	0.0000
Killer whale	0.0000	0.0000
Long-finned pilot whale	0.0000	0.0000
Phocoenidae		
Harbor porpoise [f]	0.0000	0.0002
Mysticetes		
North Atlantic right whale	*0.0000*	*0.0000*
Bowhead whale [b]	*0.0064*	*0.0256*
Gray whale [c]	0.0045	0.0179
Humpback whale	*0.0000*	*0.0000*
Minke whale	0.0000	0.0000
Sei whale	*0.0000*	*0.0000*
Fin whale	*0.0000*	*0.0000*
Blue whale	*0.0000*	*0.0000*
Pinnipeds		
Walrus [f]	0.0003	0.0010
Bearded seal [d]	0.0128	0.0226
Harbor seal	0.0000	0.0000
Spotted seal [f]	0.0001	0.0005
Ringed seal [e]	0.2510	0.4440
Hooded seal	0.0000	0.0000
Harp seal	0.0000	0.0000
Carnivora		
Polar bear [g]	0.0016	0.0040

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so that CVs would not be comparable.

[b] Calculated from summer surveys by Moore et al. (2000a) in the Alaskan Beaufort Sea; most sightings were far to the east of the proposed seismic survey. Maximum densities are assumed to be one half of the observed densities, and mean densities are assumed to be 1/8th of observed densities.

[c] Calculated from summer surveys by Moore et al. (2000a) in the Chukchi Sea; most sightings were far to the southwest of the proposed seismic survey or along the coast near Pt. Barrow. Maximum densities are assumed to be one half of the observed densities, and mean densities are assumed to be 1/8th of observed densities.

[d] Ringed seal density ×0.051 based on the ratio of ringed-to-bearded seals in Stirling et al. (1982).

[e] Average density is the mean pack-ice density from Kingsley (1986); maximum density is average density ×4.

[f] There are no reliable survey data for these species in the present area. As they are known to occur in the proposed seismic survey area (primarily near Barrow),we have arbitrarily inserted densities based on their relative abundance.

[g] Estimated from sightings and effort in Moulton and Williams (2003).

The estimated numbers of potential exposures are presented below, based on the 160 dB and, for delphinids, 170 dB re 1 μPa (rms) criteria. It is assumed that marine mammals exposed to airgun sounds that strong might change their behavior sufficiently to be considered "taken by harassment" (see § VII for a discussion of the origin of the potential disturbance isopleths).

Pinnipeds

In polar regions, most pinnipeds are associated with sea ice and census methods count pinnipeds when they are hauled out on ice. Depending on the species and study, a correction factor for the proportion of animals hauled out at any one time may or may not have been applied (depending whether they were available for the particular species and area). By applying this correction factor, the total density of pinniped species in an area can be estimated. Only the animals in the water would be exposed to the pulsed sounds from the airguns (and sonars) and the densities that are presented generally represent all animals in the area. Therefore, only a fraction of the pinnipeds present in any given area would be exposed to seismic sounds during the proposed seismic survey.

Extensive surveys of ringed and bearded seals have been conducted in the Beaufort Sea, but most surveys have been conducted over the landfast ice and few seal surveys have been in open water or in the pack ice, where much of the proposed seismic survey will be conducted. Kingsley (1986) conducted ringed seal surveys of the offshore pack ice in the central and eastern Beaufort Sea during late spring. These surveys provide the most relevant information on densities of ringed seals there. Because no surveys have been conducted in the majority of the proposed seismic survey area, these densities in combination with general information on ringed seal distribution were used for other parts of the proposed survey area. Densities for other common pinnipeds were estimated by multiplying ringed seal densities by the ratio of the population size of the other species to that for the ringed seal in the Beaufort Sea and adjacent areas (see Table 4).

Potential Number of Cetacean "Exposures" to ≥160 and ≥170 dB

The potential number of occasions when members of each species might be exposed to received levels ≥160 dB re 1 μPa (rms) was calculated for each of three water depth categories (<100 m, 100–1000 m, and >1000 m) by multiplying

- the expected species density, either "average" (i.e., best estimate) or "maximum", corrected as described above,
- the anticipated total line-kilometers of operations with the 2 G. guns or single Bolt airgun in each water-depth category after applying a 25% allowance for possible additional line kilometers as noted earlier,
- the cross-track distances within which received sound levels are predicted to be ≥160 dB for each water-depth category (Table 2).

TABLE 5. Expected densities of marine mammals in the polar pack ice **between Alaska and Svalbard**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed as endangered are in italics.

Species	Average Density [a] (# / km^2)	Maximum Density (# / km^2)
Odontocetes		
Sperm whale	*0.0000*	*0.0000*
Ziphiidae		
Northern bottlenose whale	0.0000	0.0000
Monodontidae		
Beluga [b]	0.0002	0.0007
Narwhal [c]	0.0028	0.0112
Delphinidae		
Atlantic white-beaked dolphin	0.0000	0.0000
Atlantic white-sided dolphin	0.0000	0.0000
Killer whale	0.0000	0.0000
Long-finned pilot whale	0.0000	0.0000
Phocoenidae		
Harbor porpoise	0.0000	0.0000
Mysticetes		
North Atlantic right whale	*0.0000*	*0.0000*
Bowhead whale [b]	*0.0007*	*0.0026*
Gray whale	0.0000	0.0000
Humpback whale	*0.0000*	*0.0000*
Minke whale	0.0000	0.0000
Sei whale	*0.0000*	*0.0000*
Fin whale	*0.0000*	*0.0000*
Blue whale	*0.0000*	*0.0000*
Pinnipeds		
Walrus	0.0000	0.0000
Bearded seal [b]	0.0013	0.0051
Harbor seal	0.0000	0.0000
Spotted seal	0.0000	0.0000
Ringed seal [b]	0.0111	0.0444
Hooded seal	0.0000	0.0000
Harp seal	0.0000	0.0000
Carnivora		
Polar bear	0.0002	0.0004

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so that CVs would not be comparable.

[b] Density is estimated as (the density for the area north of Barrow + the density for the area north of Svalbard)/20

[c] Average density is the density in offshore Baffin Bay from Koski and Davis corrected for *g*(0) × 0.01. Maximum density is average density ×4.

TABLE 6. Expected densities of marine mammals during surveys in the offshore pack ice **north of Svalbard**. Densities are corrected for f(0) and g(0) biases. Species listed as endangered are in italics.

Species	Average Density [a] (# / km^2)	Maximum Density (# / km^2)
Odontocetes		
Sperm whale [b]	*0.0005*	*0.0049*
Ziphiidae		
Northern bottlenose whale [c]	0.0001	0.0004
Monodontidae		
Beluga [d]	0.0001	0.0005
Narwhal [e]	0.0006	0.0023
Delphinidae		
Atlantic white-beaked dolphin [c]	0.0001	0.0004
Atlantic white-sided dolphin [c]	0.0001	0.0004
Killer whale [c]	0.0001	0.0004
Long-finned pilot whale [c]	0.0000	0.0001
Phocoenidae		
Harbor porpoise [c]	0.0000	0.0001
Mysticetes		
North Atlantic right whale [c]	*0.0000*	*0.0001*
Bowhead whale	*0.0001*	*0.0004*
Gray whale	0.0000	0.0000
Humpback whale [c]	*0.0001*	*0.0004*
Minke whale [c]	0.0001	0.0004
Sei whale [c]	*0.0000*	*0.0001*
Fin whale [c]	*0.0001*	*0.0004*
Blue whale [c]	*0.0001*	*0.0004*
Pinnipeds		
Walrus [c]	0.0001	0.0004
Bearded seal [f]	0.0128	0.0226
Harbor seal	0.0000	0.0000
Spotted seal	0.0000	0.0000
Ringed seal [f]	0.2510	0.4440
Hooded seal [g]	0.0043	0.0075
Harp seal [g]	0.0128	0.0226
Carnivora		
Polar bear	0.0016	0.0040

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so that CVs would not be comparable.

[b] The maximum density is the northeast Atlantic density from Whitehead (2002) and the average density is 10% of the maximum density because few sperm whales are expected to be found amidst the pack ice.

[c] These species are not expected to occur in the pack ice north of Svalbard. A nominal (low) average and maximum density are given.

[d] The population north of Svalbard is about 1/30th of the Beaufort population so the average and maximum estimates are assumed to be 1/30th of the Beaufort densities

[e] The narwhal population is about 1/5th of the beluga population so the narwhal density estimates are 1/5th of the beluga estimates.

[f] No data are available for these areas so the density is assumed to be the same as in the pack ice in the Beaufort Sea.

[g] The population of harp seals is approximately the same as and the population of hooded seals is approximately one third of the bearded seal population.

For the 2 G. guns, the cross track distance is 2× the predicted 160 dB radius of 9700 m for water depths <100 m, 2 × 5000 m for water depths of 100–1000 m, and 2 × 3300 m for water depths >1000 m. The numbers of exposures in the three depth categories were then summed for each species. Applying the approach described above, 18,023 km^2 would be within the 160 dB isopleth. After adding the aforementioned 25% contingency, the number of exposures is calculated based on 22,529 km^2.

Based on this method, the "best" and "maximum" estimates of the numbers of marine mammal exposures to airgun sounds with received levels ≥160 dB re 1 µPa (rms) were obtained using the average and "maximum" densities from Tables 4-6. The estimates show that two endangered cetacean species (the bowhead whale and sperm whale) may be exposed to such noise levels unless they avoid the approaching survey vessel before the received levels reach 160 dB. For convenience, we refer to either eventuality as an "exposure". Our respective best and maximum estimates for bowhead whales are 60 and 238, respectively, and for sperm whales those estimates are 0 and 5, respectively (Table 7). Though there is a slight chance of encountering a Northeast Atlantic bowhead, these estimates for bowheads concern Bering-Chukchi-Beaufort animals. Five additional endangered cetacean species that theoretically might be encountered in the area are unlikely to be exposed. Sei, blue, fin, humpback and North Atlantic right whales occasionally occur near the area, but given their low "best estimates" of densities in the area, none are likely to be exposed to ≥160 dB given the planned levels of seismic survey effort in the three depth strata.

Most of the cetacean "exposures" to seismic sounds ≥160 dB would involve mysticetes (bowheads and gray whales) and monodontids (belugas and narwhals). Best and maximum estimates of the number of exposures of cetaceans other than bowheads, in descending order, are narwhals (39 and 156 exposures), gray whales (35 and 141), and belugas (29 and 117). The regional breakdown of these numbers is shown in Table 7. Estimates for other species are lower (Table 7).

The far right column in Table 7, "Requested Take Authorization", shows the numbers of animals for which "harassment take authorization" is requested. For the common species, the requested numbers are calculated as indicated above, based on the maximum densities calculated from the data reported in the different studies mentioned above. In some cases, the requested numbers are somewhat higher than the maximum estimated numbers of exposures found in the second last column of Table 7. Some of the marine mammal species that are known or suspected to occur at least occasionally in arctic waters were not recorded during the limited systematic surveys used to estimate densities. In those cases, the "Requested Take Authorization" figures include upward adjustments for small numbers that might be encountered.

Potential Number of Pinnipeds that Might be Affected

As discussed above, there are few survey data that document pinniped distribution and densities within the proposed project area and no data that document their densities while they are in the water. The most relevant surveys were conducted on ringed seals in the Beaufort Sea by Kingsley (1986). Data from those surveys and information on relative population sizes for other species have been used to estimate numbers of pinnipeds that might be affected by 2 G. guns or the single Bolt airgun.

TABLE 7. Estimates of the possible numbers of marine mammal exposures to 160 dB and (for delphinids and pinnipeds) 170 dB during UAF's proposed seismic program in the polar pack ice between Alaska and Svalbard, August–September 2005. The proposed sound sources are two G. guns with volume 250 in^3 each or a single Bolt airgun with volume 1200 in^3. Received levels of airgun sounds are expressed in dB re 1 μPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids and pinnipeds are unlikely to react to levels below 170 dB. Species in italics are listed under the U.S. ESA as endangered. The rightmost column of numbers (in boldface) shows the numbers of "harassment takes" for which authorization is requested.

	Number of Exposures to Sound Levels ≥160 dB (≥170 dB, Less Responsive Groups)								
	Best Estimate				Maximum Estimate				Requested Take Authorization
Species	**Barrow**	**Polar Pack**	**Svalbard**	**Total**	**Barrow**	**Polar Pack**	**Svalbard**	**Total**	
Delphinidae									
Atlantic white-beaked dolphin	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**10**
Atlantic white-sided dolphin	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**10**
Killer whale	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**5**
Long-finned pilot whale	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**10**
Total Delphinidae	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	
Odontocetes									
Sperm whale	*0*	*0*	*0*	*0*	*0*	*0*	*5*	*5*	***5***
Ziphiidae									
Northern bottlenose whale	0	0	0	0	0	0	0	0	**5**
Monodontidae									
Beluga	27	2	0	29	107	10	0	117	**117**
Narwhal	0	38	1	39	1	153	2	156	**156**
Phocoenidae									
Harbor porpoise	0	0	0	0	2	0	*0*	2	***5***
Mysticetes									
North Atlantic right whale	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***2***
Bowhead whale	*51*	*9*	*0*	*60*	*202*	*36*	*0*	*238*	***238***
Gray whale	35	0	0	35	141	0	0	141	**141**
Humpback whale	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***5***
Minke whale	0	0	0	0	0	0	0	0	***5***
Sei whale	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***5***
Fin whale	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***5***
Blue whale	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***5***
Total Other Cetaceans	**113**	**50**	**2**	**164**	**452**	**198**	**10**	**661**	
Pinnipeds									
Walrus	2 (1)	0 (0)	0 (0)	2 (1)	8 (3)	0 (0)	0 (0)	8 (3)	
Bearded seal	101 (34)	17 (5)	12 (5)	131 (44)	179 (61)	70 (20)	21 (8)	270 (89)	**270**
Harbor seal	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**2**
Spotted seal	1 (0)	0 (0)	0 (0)	1 (0)	4 (1)	0 (0)	0 (0)	4 (1)	**5**
Ringed seal	1986 (676)	152 (44)	236 (89)	2373 (808)	3512 (1195)	607 (177)	417 (157)	4536 (1528)	**4536**
Hooded seal	0 (0)	0 (0)	4 (2)	4 (2)	0 (0)	0 (0)	7 (3)	7 (3)	**7**
Harp seal	0 (0)	0 (0)	12 (5)	12 (5)	0 (0)	0 (0)	21 (8)	21 (8)	**21**
Total Pinnipeds	**2090 (711)**	**169 (49)**	**264 (99)**	**2523 (859)**	**3703 (1260)**	**677 (197)**	**467 (175)**	**4847 (1632)**	
Carnivora									
Polar bear	13	2	2	16	32	5	4	41	

Ringed Seals

The ringed seal is the most widespread and abundant pinniped in ice-covered arctic, waters and there is a great deal of annual variation in population size and distribution of these marine mammals. They account for the vast majority of marine mammals expected to be encountered, and hence exposed to seismic sounds ≥160 dB re 1 μPa (rms) during the proposed seismic survey. The best (and maximum) estimate is that 2372 (4536) ringed seals might be exposed to seismic sounds ≥160 dB, accounting for 88% of the marine mammals that might be so exposed. This exposure estimate assumes that all ringed seals encountered would be in the water, but many will actually be hauled out on ice where they would not be exposed to water-borne seismic sounds. Thus the actual number of ringed seals exposed is likely to be much lower. In addition, the density that was used to estimate the numbers exposed was from pack ice farther south than the proposed survey area. Densities of ringed seals are expected to decline with increasing latitude, although there are no quantitative data to confirm this.

Pinnipeds are not likely to react to seismic sounds unless they are ≥170 dB re 1 μPa (rms), and many of those exposed to 170 dB also will not react overtly (Harris et al. 2001; Moulton and Lawson 2002). In any event, the best and maximum estimates of numbers of ringed seals that might be exposed to sounds ≥170 dB are 808 and 1528, respectively, if all seals encountered were in the water.

Other Pinniped Species

Five other species of pinnipeds are expected to be encountered during the proposed trans-Arctic seismic survey; one other species (harbor seal) is unlikely to be encountered, but its presence cannot be ruled out (Table 7). The species expected to be encountered are bearded seal (131 and 270, best and maximum estimates, respectively), harp seal (12 and 21), hooded seal (4 and 7), walrus (2 and 8) and spotted seal (1 and 4; Table 7). Since pinnipeds are not likely to react to seismic sounds unless they are ≥170 dB, the more relevant numbers for bearded seals are 44 and 89, respectively, and the numbers for other species range from 0–5 (best estimates) and 1–8 (maximum estimates), As mentioned above for ringed seals, many of these animals will be hauled out on ice, and therefore would not be exposed to the strong seismic sounds that they would be exposed to if they were in the water.

Conclusions

The proposed survey across the Arctic Ocean will involve towing two airgun configurations that introduce pulsed sounds into the ocean, along with simultaneous operation of a multi-beam sonar and hydrographic echo sounder, and the use of a pinger during coring. Routine vessel operations, other than the proposed operations by the airgun(s), are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". For similar reasons, no "taking" is expected when the vessel is conducting scientific coring. No "taking" of marine mammals is expected in association with operations of the multi-beam sonar, sub-bottom profiler, or pinger given the considerations discussed in § I and VII, i.e. sonar sounds are beamed downward, the beam is narrow, and the pulses are extremely short.

Cetaceans

Strong avoidance reactions by several species of mysticetes to seismic vessels operating large arrays of airguns have been observed at ranges up to 6–8 km and occasionally as far as 20–30 km from the source vessel. However, reactions at the longer distances appear to be atypical of most species and situations, particularly when feeding whales are involved (Miller et al. 2005). Of the small numbers of mysticetes that will be encountered in the Arctic Ocean, many are likely to be feeding at the time of the proposed seismic survey. In addition, the airgun configurations to be used in this project are less powerful than the sources that elicited avoidance at distances of several kilometers or more. Furthermore, the estimated 160 and 170 dB radii used here are probably overestimates of the actual 160 and 170 dB radii at water depths ≥100 m based on the few calibration data obtained in deep water (Tolstoy et al. 2004a,b). Thus, the estimated numbers presented in Table 7 are most likely to overestimate actual numbers.

Odontocete reactions to seismic pulses, or at least the reactions of delphinids, are expected to be limited to lesser distances from the airgun(s) than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and delphinids are often seen from seismic vessels. However, no delphinids are expected to be encountered during the trans-Arctic seismic survey.

Taking into account the small total volume and relatively low sound output of the airgun sources, and mitigation measures that are planned, effects on cetaceans are generally expected to be limited to avoidance of a small area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the population sizes in the Arctic Ocean, as described below.

Based on the 160 dB criterion, the *best estimates* of the numbers of *individual* cetaceans that may be exposed to sounds ≥160 dB re 1 μPa (rms) represent <1% of the populations of each species in the Arctic Ocean and adjacent waters (*cf*. Table 4). For species listed as ***Endangered*** under the ESA, our estimates include no North Atlantic right whales, humpback, sei whales, fin or blue whales; <0.1% of the Northeast Atlantic Ocean population of sperm whales, and ≤0.6% of the Bering-Chukchi-Beaufort bowhead whale population of >10,470+ (*cf*. Table 4). In the cases of belugas, narwhals and gray whales, the potential reactions are expected to involve no more than small numbers (29 to 35) of exposures.

It is unlikely that any North Atlantic right whales (or Northeast Atlantic bowheads) will be exposed to seismic sounds ≥160 dB re 1 μPa (rms). However, we request authorization to expose up to two North Atlantic right whales to ≥160 dB, given the possibility of encountering one or more of this endangered species. If a right whale is sighted by the vessel-based observers, or if a bowhead is sighted in the Svalbard area, the airgun(s) will be shut down regardless of the distance of the whale from the airgun(s).

Low numbers of monodontids may be exposed to sounds produced by the 1 or 2 airguns during the proposed seismic study, and the numbers potentially affected are small relative to the population sizes (Table 7). The best estimates of the numbers of belugas and narwhals that might be exposed to ≥160 dB represent <1% of their populations. This assumes that narwhals encountered in the polar pack ice in the central Arctic Ocean belong to the Baffin Bay–Davis Strait population. If they are actually members of the East Greenland population, then the estimated size of that population is too low because it did not include surveys of the central Arctic Ocean.

Varying estimates of the numbers of marine mammals that might be exposed to sounds from the single Bolt airgun or 2 G. guns during the 2005 trans-Arctic seismic survey have been presented, depending on the specific exposure criteria (≥160 vs. ≥170 dB) and density criteria used (best vs. maximum). The requested "take authorization" for each species is based on the estimated *maximum number of exposures* to ≥160 dB re 1 μPa (rms), i.e., the highest of the various estimates. That figure *likely overestimates* the actual number of animals that will be exposed to the sound levels; the reasons for this are outlined above. Even so, the estimates for the proposed survey are quite low percentages of the population sizes. The relatively short-term exposures that will occur are not expected to result in any long-term negative consequences for the individuals or their populations.

The many reported cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, course alteration, look outs, non-pursuit, and power- or shut-downs when marine mammals are seen within defined ranges will further reduce short-term reactions, and minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds

Several pinniped species are likely to be encountered in the study area, but the ringed seal is by far the most abundant marine mammal that will be encountered during the trans-Arctic seismic survey. An estimated 808 ringed seals, 44 bearded seals, and 0–5 harp, hooded and spotted seals and walruses (<0.1% their Arctic Ocean and adjacent waters populations) may be exposed to airgun sounds at received levels ≥170 dB re 1 μPa (rms) during the seismic survey. It is probable that only a small percentage of those would actually be disturbed.

As for cetaceans, the short-term exposures of pinnipeds to airgun sounds are not expected to result in any long-term negative consequences for the individuals or their populations.

Polar Bears

Effects on polar bears are anticipated to be minor at most. Although the best estimate of polar bears that will be encountered during the survey is 16, almost all of these would be on the ice, and therefore they would be unaffected by underwater sound from the airgun(s). For the few bears that are in the water, levels of airgun and sonar sound would be attenuated because polar bears generally do not dive much below the surface. Received levels of airgun sound are reduced substantially just below the surface, relative to those at deeper depths, because of the pressure release effect at the surface.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

Subsistence in Alaska

Subsistence hunting and fishing continue to be prominent in the household economies and social welfare of some Alaskan residents, particularly among those living in small, rural villages (Wolfe and Walker 1987). Subsistence remains the basis for Alaska Native culture and community. In rural Alaska, subsistence activities are often central to many aspects of human existence, including patterns of family life, artistic expression, and community religious and celebratory activities. Because of the importance of subsistence, the National Science Foundation offers guidelines for science coordination with native Alaskans at http://www.arcus.org/guidelines/.

Subsistence hunting

Marine mammals are legally hunted in Alaskan waters near Barrow by coastal Alaska Natives; species hunted include bowhead whales, beluga whales, ringed, spotted, and bearded seals, walrus, and polar bears. In the Barrow area, bowhead whales provided ~69% of the total weight of marine mammals harvested from April 1987 to March 1990. During that time, ringed seals were harvested the most on a numerical basis (394 animals).

Bowhead whale hunting is the key activity in the subsistence economies of Barrow and two smaller communities to the east, Nuiqsut and Kaktovik. The whale harvests have a great influence on social relations by strengthening the sense of Inupiat culture and heritage in addition to reinforcing family and community ties.

An overall quota system for the hunting of bowhead whales was established by the International Whaling Commission (IWC) in 1977; the quota is now regulated through an agreement between the NMFS and the Alaska Eskimo Whaling Commission (AEWC). The AEWC allots the number of bowhead whales that each whaling community may harvest annually (USDI/BLM 2005).

The community of Barrow hunts bowhead whales in both the spring and fall during the whales' seasonal migrations along the coast. Often, the bulk of the Barrow bowhead harvest is taken during the spring hunt (Table 8). However, with larger quotas in recent years, it is common for a substantial fraction of the annual Barrow quota to remain available for the fall hunt. The communities of Nuiqsut and Kaktovik participate only in the fall bowhead harvest. The spring hunt at Barrow occurs after leads open due to the deterioration of pack ice; the spring hunt typically occurs from early April until the first week of June. The fall migration of bowhead whales that summer in the eastern Beaufort Sea typically begins in late August or September. The location of the fall subsistence hunt depends on ice conditions and (in some years) industrial activities that influence the bowheads movements as they move west (Brower 1996). In the fall, subsistence hunters use aluminum or fiberglass boats with outboards. Hunters prefer to take bowheads close to shore to avoid a long tow during which the meat can spoil, but Braund and Moorehead (1995) report that crews may (rarely) pursue whales as far as 80 km. The autumn hunt at Barrow usually begins in mid-September, and mainly occurs in the waters east and northeast of Point Barrow. The whales have usually left the Beaufort Sea by late October (Treacy 2002a,b).

The scheduling of this seismic survey has been discussed with representatives of those concerned with the subsistence bowhead hunt, most notably the AEWC, the Barrow Whaling Captains' Association (BWCA), and the North Slope Borough Dept of Wildlife Management. For this among other reasons, the project has been scheduled to commence in early August, well before the start of the fall hunt at Barrow (or Nuiqsut or Kaktovik), to avoid possible conflict with whalers.

Beluga whales are available to subsistence hunters at Barrow in the spring when pack-ice conditions deteriorate and leads open up. Belugas may remain in the area through June and sometimes into July and August in ice-free waters. Hunters usually wait until after the bowhead whale hunt is finished before turning their attention to hunting belugas. The average annual harvest of beluga whales taken by Barrow for 1962–1982 was five (Table 9; MMS 1996). The Alaska Beluga Whale Committee recorded that 23 beluga whales had been harvested by Barrow hunters from 1987 to 2002, ranging from 0 in 1987, 1988 and 1995 to the high of 8 in 1997 (Fuller and George 1999; Alaska Beluga Whale Committee 2002 *in* USDI/BLM 2005). The timing of the proposed survey and beluga harvest do not overlap.

TABLE 8. Bowhead landings[1] at Barrow, 1993-2003. From Burns et al. (1993), various issues of *Report of the International Whaling Commission*, Alaska Eskimo Whaling Commission, and J.C. George (NSB Dep. Wildl. Manage.), compiled by LGL Alaska Res. Assoc. (2004).

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Number	23/7	16/1	20/11	24/19	31/21	25/16	24/6	18/13	26/7	20/17	16/6	?/14

[1] Numbers given are "total landings/autumn landings".

TABLE 9. Average annual take of marine mammals other than bowhead whales harvested by the community of Barrow (as compiled by LGL Alaska Res. Assoc. 2004).

Beluga Whales	Ringed Seals	Bearded Seals	Spotted Seals
5**	394*	174*	1*

* Average annual harvest for years 1987-90 (Braund et al. 1993).

** Average annual harvest for years 1962-82 (MMS 1996).

Ringed seals are hunted near Barrow mainly from October through June. Hunting for these smaller mammals is concentrated during winter because bowhead whales, bearded seals and caribou are available through other seasons. Winter leads in the area off Pt. Barrow and along the barrier islands of Elson Lagoon to the east are used for hunting ringed seals. The average annual ringed seal harvest by the community of Barrow has been estimated as 394 (Table 9). Although ringed seals are available year-round, the seismic survey will not occur during the primary period when these seals are harvested.

The ***spotted seal*** subsistence hunt peaked in July and August, at least in 1987 to 1990, but involves few animals. Spotted seals typically migrate south by October to overwinter in the Bering Sea. Admiralty Bay, <60 km to the east of Barrow, is a location where spotted seals are harvested. Spotted seals are also occasionally hunted in the area off Pt. Barrow and along the barrier islands of Elson Lagoon to the east (USDI/BLM 2005). The average annual spotted seal harvest by the community of Barrow is ~3 (also see Table 9). The seismic survey will commence at least 40 km offshore from the preferred nearshore harvest area of these seals.

Bearded seals, although not favored for their meat, are important to subsistence activities in Barrow because of their skins. Six to nine bearded seal hides are used by whalers to cover each of the skin-covered boats traditionally used for spring whaling. Because of their valuable hides and large size, bearded seals are specifically sought. Bearded seals are harvested during the summer months in the Beaufort Sea (USDI/BLM 2005). The animals inhabit the environment around the ice floes in the drifting ice pack, so hunting usually occurs from boats in the drift ice. Braund et al. (1993) mapped the majority of bearded seal harvest sites from 1987 to 1990 as being within ~24 km of Point Barrow. The average annual take of bearded seals by the Barrow community from 1987 to 1990 was 174 (Table 9).

The USFWS has monitored the harvest of ***polar bears*** in Alaska using a mandatory marking, tagging, and reporting program implemented in 1988. Polar bears are harvested in the winter and spring, but comprise a small percent of the annual subsistence harvest. Braund et al. (1993) reported that ~2% of the total edible pounds harvested by Barrow residents from 1987 to 1989 involved polar bears. The USFWS estimated that, from 1995 to 2000, the average annual harvest of the Southern Beaufort Sea polar bear stock in Alaska was 32 (Angliss and Lodge 2004). That would include harvests at other smaller communities besides Barrow.

Walruses are hunted primarily from June through mid-August to the west of Point Barrow and southwest to Peard Bay. (Walruses rarely occur in the Beaufort Sea north and east of Barrow.) The harvest effort peaks in July. The annual walrus harvest by Barrow residents ranged from 7 to 206 animals from 1990 to 2002 (Fuller and George 1999; Schliebe 2002 *in* USDI/BLM 2005).

In the event that both marine mammals and hunters would be near the *Healy* when it begins operating north of Barrow, the proposed project potentially could impact the availability of marine mammals for harvest in a very small area immediately around the *Healy*. However, the majority of marine mammals are taken by hunters within ~33 km off shore (Fig. 5), and the *Healy* is expected to commence the seismic survey farther offshore than that. Operations there are scheduled to occur in August, and hunting in offshore waters generally does not occur at that time of year. (The bowhead hunt near Barrow normally does not begin until more than a month later.) Considering that, and the limited times and location where the planned seismic survey overlaps with hunting areas, the proposed project is not expected to have any significant impacts to the availability of marine mammals for subsistence harvest.

Subsistence fishing

Subsistence fishing is conducted by Barrow residents through the year, but most actively during the summer and fall months. Barrow residents often fish for camp food while hunting, so the range of subsistence fishing is widespread. Marine subsistence fishing occurs during the harvest of other subsistence resources in the summer. Most fishing occurs closer to Barrow than where the survey will be conducted (MMS 1996).

Seismic surveys can, at times, cause changes in the catchability of fish (see § IX below). UAF will minimize the potential for negative impacts on the subsistence fish harvest by avoiding seismic operations in areas where subsistence fishers are fishing. In the unlikely event that subsistence fishing (or hunting) is occurring within 5 km of the *Healy's* trackline, the airgun operations will be suspended until the *Healy* is >5 km away.

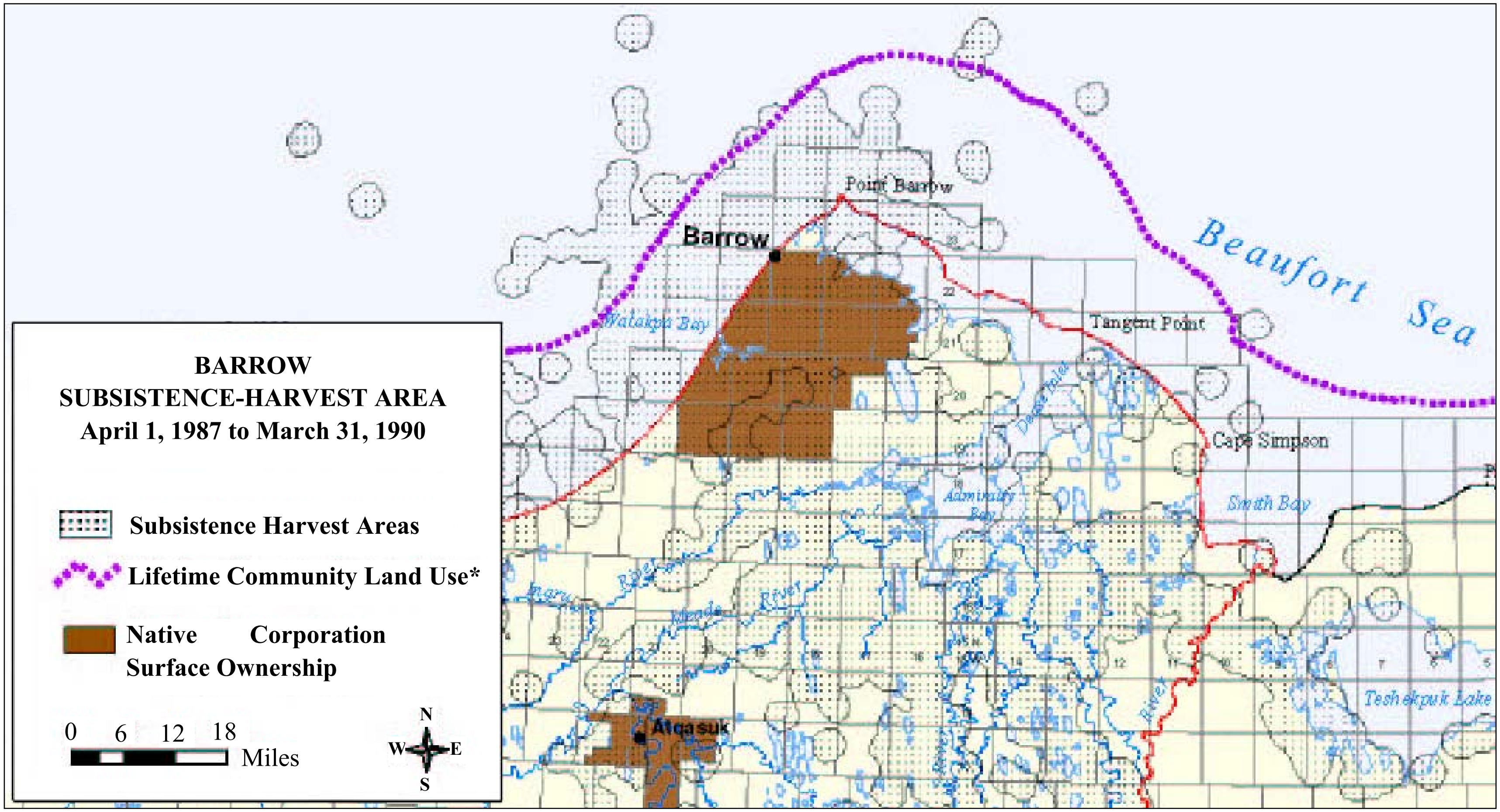
Subsistence in Svalbard

In Norwegian waters, a limited amount of subsistence hunting takes place on and near Svalbard. The human population of Svalbard is ~1700. Of the marine mammals found near Svalbard only the minke whale, bearded seal, and ringed seal may be taken by local hunters. The commercial sealing grounds for harp and hooded seals are distant from Svalbard. The proposed activity will have no impact on the subsistence use of marine resources in Svalbard's territorial waters. The seismic survey is to terminate northwest of Svalbard territorial waters. Any ship operations closer to Svalbard will be similar to those of other vessels operating in the area, will not involve airgun operations, and will not adversely affect subsistence harvests. UAF is applying to the Norwegian Directorate of Fisheries and the NPD for a permit to operate in Norway's EEZ.

IX. ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. Although feeding bowhead whales may occur in the area, the proposed activities will be of short duration in any particular area at any given time; thus any effects would be localized and short-term. However, the main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in § VI/VII, above.



* The lifetime use line represents the areas used by 20 hunters over their lifetimes up to 1979 (Pederson 1979 *in* Braund et al. 1993).
Source: Map 72. USDI/BLM 2003

FIGURE 5. Barrow subsistence harvest areas, April 1987 to March 1990, indicating the extent offshore where subsistence hunting is conducted. Source: Map 72. (USDI/BLM 2003).

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that, unlike explosives, they do not result in any appreciable fish kill. However, the existing body of information relating to the impacts of seismic on marine fish and invertebrate species is very limited. The various types of potential effects of exposure to seismic on fish and invertebrates can be considered in three categories: (1) pathological, (2) physiological, and (3) behavioral. Pathological effects include lethal and sub-lethal damage to the animals, physiological effects include temporary primary and secondary stress responses, and behavioral effects refer to changes in exhibited behavior of the fish and invertebrates. The three categories are interrelated in complex ways. For example, it is possible that certain physiological and behavioral changes could potentially lead to the ultimate pathological effect on individual animals (i.e., mortality).

The available information on the impacts of seismic surveys on marine fish and invertebrates provides limited insight on the effects only at the individual level. Ultimately, the most important knowledge in this area relates to how significantly seismic affects animal populations.

The following sections provide an overview of the available information on the effects of seismic surveys on fish and invertebrates. The information comprises results from various scientific studies as well as some anecdotal information.

Pathological Effects.—In water, acute injury and death of organisms exposed to seismic energy depends primarily on two features of the sound source: (1) the received peak pressure, and (2) the time required for the pressure to rise and decay (Hubbs and Rechnitzer 1952). Generally, the higher the received pressure and the less time it takes for the pressure to rise and decay, the greater the chance of acute pathological effects. Considering the peak pressure and rise/decay time characteristics of seismic airgun arrays used today, the pathological zone for fish and invertebrates would be expected to be within a few meters of the seismic source (Buchanan et al. 2004). For the proposed survey, any injurious effects on fish would be limited to very short distances, especially considering the low-energy sources planned for use in this project.

Matishov (1992) reported that some cod and plaice died within 48 hours of exposure to seismic pulses 2 m from the source. No other details were provided by the author. On the other hand, there are numerous examples of no fish mortality as a result of exposure to seismic sources (Falk and Lawrence 1973; Holliday et al. 1987; La Bella et al. 1996; Santulli et al. 1999; McCauley et al. 2000a,b, 2003; Bjarti 2002; IMG 2002; Hassel et al. 2003).

There are examples of damage to fish ear structures from exposure to seismic airguns (McCauley et al. 2000a,b, 2003), but it should be noted the experimental fish were caged and exposed to high cumulative levels of seismic energy. It is noteworthy that Atlantic salmon were exposed within 1.5 m of underwater explosions exhibited no mortality either was observed immediately after exposure or during the seven-day monitoring period following exposure (Sverdrup et al. 1994). Compared to airgun sources, explosive detonations are characterized by higher peak pressures and more rapid rise and decay times, and are considered to have greater potential to damage marine biota. In spite of this, no mortality was evident.

Some studies have also provided information on the effects of seismic exposure on fish eggs and larvae (Kostyuchenko 1972; Dalen and Knutsen 1986; Holliday et al. 1987; Matishov 1992; Booman et al. 1996; Dalen et al. 1996). Overall, impacts appeared to be minimal and any mortality was generally not significantly different from the experimental controls. Generally, any observed larval mortality occurred after exposures within 0.5–3 m of the airgun source. Matishov (1992) did report some retinal tissue damage in cod larvae exposed at 1 m from the airgun source. Saetre and Ona (1996) applied a 'worst-case scenario' mathematical model to investigate the effects of seismic energy on fish eggs and larvae, and concluded that mortality rates caused by exposure to seismic are so low compared to natural mortality that the impact of seismic surveying on recruitment to a fish stock must be regarded as insignificant.

The pathological impacts of seismic energy on some marine invertebrate species have also been investigated. Christian et al. (2003) exposed adult male snow crabs, egg-carrying female snow crabs, and fertilized snow crab eggs to energy from seismic airguns. Neither acute nor chronic (12 weeks after exposure) mortality was observed for the adult male and female crabs. However, a significant difference in development rate was noted between the exposed and unexposed fertilized eggs. The egg mass exposed to seismic energy had a higher proportion of less-developed eggs than the unexposed mass. It should be noted that both egg masses came from a single female and that any measure of natural variability was unattainable.

Pearson et al. (1994) exposed Stage II larvae of the Dungeness crab to single discharges from a seven-airgun seismic array and compared their mortality and development rates with those of unexposed larvae. For immediate and long-term survival and time to molt, this field experiment did not reveal any statistically-significant differences between the exposed and unexposed larvae, even those exposed within 1 m of the seismic source.

Bivalves of the Adriatic Sea were also exposed to seismic energy and subsequently assessed (LaBella et al. 1996). No effects of the exposure were noted.

To date, there have not been any well-documented cases of acute post-larval fish or invertebrate mortality as a result of exposure to seismic sound under normal seismic operating conditions. Sub-lethal injury or damage has been observed, but generally as a result of captive exposure to very high received levels of sound, significantly higher than the received levels generated by the airgun(s) that are planned for use during the proposed study. Acute mortality of eggs and larvae have been demonstrated in experimental exposures, but only when the eggs and larvae were exposed very close to the seismic sources and the received pressure levels were presumably very high. The available limited information has not indicated any chronic mortality as a direct result of exposure to seismic sounds.

Physiological Effects.—Biochemical responses by marine fish and invertebrates to acoustic stress have also been studied, although in a limited way. Studying the variations in the biochemical parameters influenced by acoustic stress might give some indication of the extent of the stress and perhaps forecast eventual detrimental effects. Such stress could potentially affect animal populations by reducing reproductive capacity and adult abundance.

McCauley et al. (2000a,b) used various physiological measures to study the physiological effects of exposure to seismic energy on various fish species, squid, and cuttlefish. No significant increases in physiological stress increases attributable to seismic energy were detected. Sverdrup et al. (1994) found that Atlantic salmon subjected to acoustic stress released primary stress hormones, adrenaline and cortisol, as a biochemical response although there were different patterns of delayed increases for the different indicators. Caged European sea bass were exposed to seismic energy and numerous biochemical responses were indicated. All returned to their normal physiological levels within 72 hours of exposure.

Stress indicators in the haemolymph of adult male snow crabs were monitored after exposure of the animals to seismic energy (Christian et al. 2003). No significant differences between exposed and unexposed animals were found in the stress indicators (e.g., proteins, enzymes, cell type count).

Primary and secondary stress responses of fish after exposure to seismic energy all appear to be temporary in any studies done to date. The times necessary for these biochemical changes to return to normal are variable depending on numerous aspects of the biology of the species and of the sound stimulus.

Summary of Physical (Pathological and Physiological) Effects.—As indicated in the preceding general discussion, there is a relative lack of knowledge about the potential physical (pathological and physiological) effects of seismic energy on marine fish and invertebrates. Available data suggest that there may be physical impacts on eggs and on, larval, juvenile, and adult stages at very close range. Considering typical source levels associated with commercial seismic arrays, close proximity to the source would result in exposure to very high energy levels. Again, this study will employ sound sources that will generate low energy levels. Whereas egg and larval stages are not able to escape such exposures, juveniles and adults most likely would avoid them. In the cases of eggs and larvae, it is likely that the numbers adversely affected by such exposure would be small in relation to natural mortality. Limited data regarding physiological impacts on fish and invertebrates indicate that these impacts are short-term and are most apparent after exposure at close range.

The proposed Arctic Ocean seismic program for 2005 is predicted to have negligible to low physical effects on the various life stages of fish and invertebrates for its ~53 day duration and 4060-km extent. Therefore, physical effects of the proposed program on the fish and invertebrates would be not significant.

***Detection and Production of Sounds by Fish and Invertebrates*.—**Hearing in fishes was first demonstrated in the early 1900s through studies involving cyprinids (Parker 1903 and Bigelow 1904 *in* Kenyon et al. 1998). Since that time, numerous methods have been used to test auditory sensitivity in fishes, resulting in audiograms of over 50 species. These data reveal great diversity in fish hearing ability, mostly attributable to various peripheral modes of coupling the ear to internal structures, including the swim bladder. However, the general auditory capabilities of less than 0.2% of fish species are known so far.

For many years, studies of fish hearing have reported that the hearing bandwidth typically extends from below 100 Hz to ~1 kHz in fishes without specializations for sound detection, and up to ~7 kHz in fish with specializations that enhance bandwidth and sensitivity. Recently there have been suggestions that certain fishes, including many clupeiforms (herring, shads, anchovies, etc.) may be capable of detecting ultrasonic signals with frequencies as high as 126 kHz (Dunning et al. 1992; Nestler et al. 1992). Studies on Atlantic cod, a non-clupeiform fish, suggested that this species could detect ultrasound at almost 40 kHz (Astrup and Møhl 1993).

Mann et al. (2001) showed that the American shad is capable of detecting sounds up to 180 kHz. They also demonstrated that the gulf menhaden is able to detect ultrasound, whereas other species such as the bay anchovy, scaled sardine, and Spanish sardine only detect sounds with frequencies up to ~4 kHz. In any event, detection of ultrasound is not of particular relevance in this situation, as the sounds from airguns are primarily at low frequency.

Among fishes, at least two major pathways for sound transmission to the ear have been identified. The first and most primitive is the conduction of sound directly from the water to tissue and bone. The fish's body takes up the sound's acoustic particle motion and subsequent hair cell stimulation occurs because of the difference in inertia between the hair cells and their overlying otoliths. These species are known as 'hearing generalists' (Fay and Popper 1999). The second sound pathway to the ears is indirect. The swim bladder or other gas bubble near the ears expands and contracts in volume in response to sound pressure fluctuations, and the motion is then transmitted to the otoliths. Although present in most bony fishes, the swim bladder is absent or reduced in many other fish species. Only some species of fish with a swim bladder appear to be sound-pressure sensitive *via* this indirect pathway to the ears; they are called 'hearing specialists'. Hearing specialists have some sort of connection with the inner ear, either *via* bony structures known as Weberian ossicles, extensions of the swim bladder, or a swim bladder more proximate to the inner ear. Hearing specialists' sound-pressure sensitivity is high and their upper frequency range of detection is extended above those species that hear only by the direct pathway. Typically, most fish detect sounds of frequencies up to 2000 Hz but, as indicated, others have detection ranges that extend to much higher frequencies.

Fish also possess lateral lines that detect water movements. The essential stimulus for the lateral line consists of differential water movement between the body surface and the surrounding water. The lateral line is typically used in concert with other sensory information, including hearing (Sand 1981; Coombs and Montgomery 1999).

Elasmobranchs (sharks and skates) lack any known pressure-to-displacement transducers such as swim bladders. Therefore, they presumably must rely on the displacement sensitivity of their mechanoreceptive cells. Unlike acoustic pressure, the kinetic stimulus is inherently directional but its magnitude rapidly decreases relative to the pressure component as it propagates outward from the sound source in the near field. It is believed that elasmobranches are most sensitive to frequencies below 1 kHz (Corwin 1981).

Because they lack air-filled cavities and are often the same density as water, invertebrates detect underwater sounds differently than fish. Rather than being pressure sensitive, invertebrates appear to be most sensitive to particle displacement. However, their sensitivity to particle displacement and hydrodynamic stimulation seem poor compared to fish. Decapods, for example, have an extensive array of hair-like receptors both within and upon the body surface that could potentially respond to water- or substrate-borne displacements. They are also equipped with an abundance of proprioceptive organs that could serve secondarily to perceive vibrations. Crustaceans appear to be most sensitive to frequencies below 1000 Hz (Budelmann 1992; Popper et al. 2001).

Many fish and invertebrates are also capable of sound production. It is believed that these sounds are used for communication in a wide range of behavioral and environmental contexts. The behaviors most often associated with acoustic communication include territorial behavior, mate finding, courtship, and aggression. Sound production provides a means of long-distance communication and communication when underwater visibility is poor (Zelick et al. 1999).

Behavioral Effects.—Because of the apparent lack of serious pathological and physiological effects of seismic energy on marine fish and invertebrates, most concern now centers on the possible effects of exposure to seismic surveys on the distribution, migration patterns, and catchability of fish. There is a need for more information on exactly what effects such sound sources might have on the detailed behavior patterns of fish and invertebrates at different ranges.

Studies investigating the possible effects of seismic energy on fish and invertebrate behavior have been conducted on both uncaged and caged animals. Studies of change in catch rate typically involve larger spatial and temporal scales than are typical for close-range studies involving caged animals (Hirst and Rodhouse 2000). Hassel et al. (2003) investigated the behavioral effects of seismic pulses on caged sand lance in Norwegian waters. The sand lance did exhibit responses to seismic sounds, including an increase in swimming rate, an upwards vertical shift in distribution, and startle responses. Normal behaviors were resumed shortly after cessation of the seismic source. None of the observed sand lance reacted by burying into the sand.

Engås et al. (1996) assessed the effects of seismic surveying on Atlantic cod and haddock behavior using acoustic mapping and commercial fishing techniques. Results indicated that fish abundance decreased at the seismic survey area, and that the decline in abundance and catch rate lessened with distance from the survey area. Trawl catch during operation of an 18-airgun, 5012 in^3 source (much larger than planned here) decreased by 44% within 9 n.mi. of the shooting and decreased by 29% within 16–18 n.mi. of the shooting. Fish abundance and catch rates had not returned to pre-seismic levels five days after cessation of airgun activity. In other airgun experiments, catch per unit effort (CPUE) of demersal fish declined when airgun pulses were emitted, particularly in the immediate vicinity of the seismic survey (Dalen and Raknes 1985; Dalen and Knutsen 1986; Løkkeborg 1991; Skalski et al. 1992). Reductions in the catch may have resulted from a change in behavior of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish may have changed their swimming and schooling behavior. Fish behavior returned to normal minutes after the sounds ceased.

Marine fish inhabiting an inshore reef off the coast of Scotland were monitored by telemetry and remote camera before, during, and after airgun firing (Wardle et al. 2001). Although some startle responses were observed, the seismic airgun firing had little overall effect on the day-to-day behavior of the resident fish.

Other species involved in studies that have indicated fish behavioral responses to underwater sound include rockfish (Pearson et al. 1992), Pacific herring (Schwarz and Greer 1984), and Atlantic herring (Blaxter et al. 1981). The responses observed in these studies were relatively temporary. However, there is no information on the potential impacts of seismic energy on fish and invertebrate behaviors that are associated with reproduction and migration.

Studies on the effects of sound on fish behavior have also been conducted using caged or confined fish. Such experiments were conducted in Australia using fish, squid, and cuttlefish as subjects (McCauley et al. 2000a,b). Common observations of fish behavior included startle response, faster swimming, movement to the part of the cage furthest from the seismic source (i.e., avoidance), and eventual habituation. Fish behavior appeared to return to a pre-seismic state 15–30 min after cessation of seismic shooting. Squid exhibited strong startle responses to the onset of proximate airgun firing by releasing ink and/or jetting away from the source. The squid consistently made use of the 'sound shadow' at the surface, where the sound intensity was less than at 3 m depth. These experiments provide more evidence that fish and invertebrate behavior may alter in response to seismic sounds, although the behavioral changes seem to be temporary.

Christian et al. (2003) conducted an experimental commercial fishery for snow crab before and after an area was exposed to seismic shooting. Although the resulting data were not conclusive, no drastic decrease in catch rate was observed after seismic shooting commenced. Another behavioral investigation by Christian et al. (2003) involved caging snow crabs, positioning the cage 50 m below a 7-airgun array, and observing the immediate responses of the crabs to the onset of seismic shooting by remote underwater camera. No obvious startle behaviors were observed. However, anecdotal information from Newfoundland, Canada, indicated that snow crab catch rates showed a significant reduction immediately following a pass by a seismic survey vessel. Other anecdotal information from Newfoundland indicated that a school of shrimp observed on a fishing vessel sounder shifted downwards and away from a nearby seismic source. Effects were temporary in both the snow crab and shrimp observations (Buchanan et al. 2004).

Summary of Behavioral Effects.—As is the case with pathological and physiological effects of seismic on fish and invertebrates, available information is relatively scant and often contradictory. There have been well-documented observations of fish and invertebrates exhibiting behaviors that appeared to be responses to exposure to seismic energy (i.e., startle response, change in swimming direction and speed, and change in vertical distribution), but the ultimate importance of those behaviors is unclear. Some studies indicate that such behavioral changes are very temporary, whereas others imply that fish might not resume pre-seismic behaviors or distributions for a number of days. There appears to be a great deal of inter- and intra-specific variability. In the case of finfish, three general types of behavioral responses have been identified: startle, alarm, and avoidance. The type of behavioral reaction appears to depend on many factors, including the type of behavior being exhibited before exposure, and proximity and energy level of the sound source.

During the proposed study, only a small fraction of the available habitat would be ensonified at any given time, and fish species would be expected to return to their pre-disturbance behavior once the seismic activity ceased. The proposed seismic survey is predicted to have negligible to low behavioral effects on the various life stages of the fish and invertebrates during the ~53 day study.

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The proposed airgun operations will not result in any permanent impact on habitats used by marine mammals or sea turtles, or to the food sources they use. Nonetheless, the main impact issue associated with the proposed activities will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed above. Sea turtles are uncommon in the area if they occur at all.

During the seismic study only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species would be short-term and fish would return to their pre-disturbance behavior once the seismic activity ceases. Thus, the proposed survey would have little, if any, impact on the abilities of marine mammals (or sea turtles) to feed in the area where seismic work is planned.

Some mysticetes feed on concentrations of zooplankton, and feeding bowhead whales may occur in the Beaufort Sea in August, when the *Healy* will be in the area. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause that type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and that would translate into negligible impacts on feeding mysticetes.

Thus, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations, since operations at the various sites will be limited in duration.

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[3] For airgun pulses, root-mean-square (rms) pressures, averaged over the pulse duration, are on the order of 10–13 dB less than peak pressure (Greene 1997; McCauley et al. 1998, 2000b).

XI. MITIGATION MEASURES

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

For the proposed seismic survey across the Arctic Ocean in August-September 2005, UAF will deploy airgun sources involving only 1 or 2 airguns. This is an inherent and important mitigation measure that will reduce the potential for effects relative to those that might occur with large airgun arrays. Also, most of the seismic survey is to be in deep water, where impact radii are least, and in the Arctic Basin, where marine mammal densities are low.

Received sound fields were modeled by L-DEO for the different airgun configurations, in relation to distance and direction from the airgun(s). The radii around the airgun(s) where received levels would be 180 and 190 dB re 1 μPa (rms) depend on water depth and are shown in Table 2. The 180 and 190 dB levels are power-down or, if necessary, shut-down criteria applicable to cetaceans and pinnipeds, respectively, as specified by NMFS (2000).

Vessel-based observers will watch for marine mammals near the airgun(s) when they are in use during daytime and during nighttime start ups. Mitigation and monitoring measures proposed to be implemented for the proposed seismic survey have been developed and refined in cooperation with NMFS during previous L-DEO seismic studies and associated EAs, IHA Applications, and IHAs. The mitigation and monitoring measures described herein represent a combination of the procedures required by past IHAs for L-DEO projects. The measures are described in detail below.

Some cetacean species (such as bowhead whales) may be feeding in the Beaufort Sea during August. However, the number of individual animals expected to be closely approached during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring, ramp-up, power-down, and shut-down provisions (see below), any effects on individuals are expected to be limited to behavioral disturbance. That is expected to have negligible impacts on the species and stocks.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity.

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime airgun operations and during any nighttime start ups of the airguns. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, airgun operations will be powered down (or shut down if necessary) immediately.

- During daylight, vessel-based observers will watch for marine mammals near the seismic vessel during all periods with shooting and for a minimum of 30 min prior to the planned start of airgun operations after an extended shut down.

- UAF proposes to conduct nighttime as well as daytime operations (though there will be little night at the start of the cruise). Observers dedicated to marine mammal observations will not be on duty during ongoing seismic operations at night. At night, bridge personnel will watch for marine mammals (insofar as practical at night) and will call for the airgun(s) to be shut down if marine mammals are observed in or about to enter the safety radii. If the airguns are started up at night, two marine mammal observers will monitor marine mammals near the source vessel for 30 min prior to start up of the airguns using night vision devices.

Proposed Safety Radii

Received sound levels were modeled by L-DEO for the different airgun configurations, in relation to distance and direction from the airgun(s) (Fig. 3, 4). The models do not allow for bottom interactions, and are most directly applicable to deep water. Based on the model, the distances from the airgun(s) where sound levels of 190, 180, 170, and 160 dB re 1 μPa (rms) are predicted to be received are shown Table 2.

Empirical data concerning the 180, 170 and 160 dB distances have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (Tolstoy et al. 2004a,b). The results are limited, and do not include measurements for the sources proposed for this study. However, the data for other airgun configurations showed that water depth affected the radii around the airguns where received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000). Similar depth-related variation is likely in the 190 dB distances applicable to pinnipeds.

Water depths within the survey area are 20–4000 m, with >94% of the survey conducted in depths >1000 m. In ***deep*** (>1000 m) water, the estimated 190 and 180 dB radii for two 250 in^3 G. guns are 100 and 325 m, respectively. Those for one 1200 in^3 Bolt airgun are 25 m and 50 m, respectively. In ***intermediate*** depths (100–1000 m), the assumed radii for the 190 and 180 dB radii in intermediate-depth water are 150 m and 500 m, respectively, for the 2 G. gun system and 38 m and 75 m, respectively, for the single Bolt airgun. For operations in ***shallow*** (<100 m) water, the radii for one airgun were assumed to be half of those for the two G. guns so the radii for the single G. gun in shallow water are 750 m for 190 db and 1200 m for 180 dB. The sound radii for the single Bolt airgun in shallow water are estimated to be 313 m for 190 dB and 370 m for 180 dB. For more a more detailed explanation on how these safety radii were derived, please refer to the section on "Airgun Description" in § I.

Airguns will be powered down (or shut down if necessary) immediately when marine mammals are detected within or about to enter the appropriate radius: 180-dB (rms) for cetaceans, and 190-dB (rms) for pinnipeds. The 180 and 190 dB shutdown criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS. UAF, L-DEO and NSF are aware that NMFS is developing new noise-exposure guidelines, but that they have not yet been finalized or approved for use. UAF, NSF, as well as L-DEO, will be prepared to revise their procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required at some future date by the new guidelines.

Mitigation During Operations

In addition to monitoring, mitigation measures that will be adopted will include (1) speed or course alteration, provided that doing so will not compromise operational safety requirements, (2) power-or shut-down procedures, (3) special mitigation measures (shut downs) for the North Atlantic right whale and Northeast Atlantic bowhead whale, because of special concern associated with their very low population sizes, and (4) no start up of airgun operations unless the full 180 dB safety zone is visible for at least 30 min during day or night.

During nighttime operations, if the entire safety radius is visible using vessel lights and NVDs[4] (as may be the case in deep waters), then start up of the 2 G. guns or single Bolt airgun may occur. However, lights and NVDs may not be very effective as a basis for monitoring the larger safety radii around the airgun(s) operating in intermediate (the 2 G. gun system) or shallow water (both the 2 G. gun system and Bolt airgun). In intermediate or shallow water, nighttime start ups of the airgun from a shut-down condition may not be possible. If the airgun has been operational before nightfall, it can remain operational throughout the night, even though the entire safety radius may not be visible.

The mitigation and marine mammal monitoring measures listed and described below will be adopted during the proposed seismic program, provided that doing so will not compromise operational safety requirements:

1. Speed or course alteration;
2. Power-down procedures;
3. Shut-down procedures; and
4. Ramp-up procedures.

Speed or Course Alteration

If a marine mammal is detected outside the safety radius and, based on its position and the relative motion, is likely to enter the safety radius, the vessel's speed and/or direct course may, when practical and safe, be changed in a manner that also minimizes the effect on the planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or power down or shut down of the airgun(s). However, in regions of complete ice cover, which are common near the North Pole, cetaceans are unlikely to be encountered because they must reach the surface to breathe.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals are not in the safety zone. A power down may also occur when the vessel is moving from one seismic line to another. During a power down, one airgun is operated. The continued operation of one airgun is intended to alert marine mammals to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's speed and/or course cannot be changed to avoid having the mammal enter the safety radius, the airguns may (as an alternative to a complete shut down) be powered down before the mammal is within the safety radius. Likewise, if a mammal is already within the safety zone when first detected, the

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[4] See Smultea and Holst (2003), Holst (2004), Smultea et al. (2004), and MacLean and Koski (2005) for an evaluation of the effectiveness of night vision equipment for nighttime marine mammal observations.

airguns will be powered down immediately if this is a reasonable alternative to a complete shut down. During a power down of the 2 G. gun system, one airgun (e.g., 250 in^3) will be operated. If a marine mammal is detected within or near the smaller safety radius around that single airgun (Table 2), the other airgun will be shut down (see next subsection).

Following a power down, airgun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it

- is visually observed to have left the safety zone, or
- has not been seen within the zone for 15 min in the case of small odontocetes and pinnipeds, or
- has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm and beaked whales.

Shut-down Procedures

The operating airgun(s) will be shut down completely if a marine mammal approaches or enters the then-applicable safety radius and a power down is not practical. The operating airgun(s) will also be shut down completely if a marine mammal approaches or enters the estimated safety radius of the source that would be used during a power down.

Airgun activity will not resume until the marine mammal has cleared the safety radius. The animal will be considered to have cleared the safety radius if it is visually observed to have left the safety radius, or if it has not been seen within the radius for 15 min (small odontocetes, pinnipeds, and sea turtles) or 30 min (mysticetes and large odontocetes, including sperm and beaked whales).

Ramp-up Procedures

A "ramp up" procedure will be followed when the G. gun cluster begins operating after a specified-duration period without airgun operations. NMFS normally requires that the rate of ramp up be no more than 6 dB per 5 min period. The specified period depends on the speed of the source vessel and the size of the airgun array that is being used. Ramp up will begin with one of the two G. guns (250 in^3). The other G. gun will be added after a period of 5 minutes. This will result in an increase of no more than 6 dB per 5-min period when going from one G. gun to the full two G. gun system, which is the normal rate of ramp up for larger airgun arrays. During the ramp up (i.e., when only one G. gun is operating), the safety zone for the full two G. gun system will be maintained.

If the complete safety radius has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence unless one G. gun has been operating during the interruption of seismic survey operations. This means that it will not be permissible to ramp up the 2 G. gun source from a complete shut down in thick fog or at other times when the outer part of the safety zone is not visible. If the entire safety radius is visible using vessel lights and/or NVDs (as may be possible under moonlit and calm conditions), then start up of the airguns from a shut down may occur at night. If one airgun has operated during a power-down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away if they choose. Ramp up of the airguns will not be initiated if a marine mammal is sighted within or near the applicable safety radii during the day or a night.

XII. Plan of Cooperation

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:

(i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;

(ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;

(iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and

(iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

UAF and the AEWC will develop a "Plan of Cooperation" for the 2005 Arctic Ocean seismic survey, in consultation with representatives of the Barrow whaling community. UAF has worked closely with the people of Barrow to identify and avoid areas of potential conflict. The PI has visited Barrow three times (17 August 2004, 1 December 2004, and 13 January 2005) to explain the survey plans to the local residents and discuss their concerns.

- August 2004 – The PI met with the president of the BWCA, Mr. Eugene Brower, to discuss the objectives of the cruise. Mr. Brower supported the fact that the survey would not be conducted during the typical timing of bowhead migration or harvest.
- December 2004 – The Barrow Arctic Science Consortium sponsored a school presentation by the PI about the objectives for the cross-basin survey. The public presentation was widely advertised in Barrow via posters and radio. During his visit, the PI spoke with the Executive Director of the AEWC and BWCA, including the BWCA president.
- January 2005 – The PI presented information about the survey at the BWCA's annual meeting. The BWCA president and ~50 whaling captains, or their representatives, were in attendance.

The PI has also discussed the survey and his project objectives with North Slope Borough Department of Wildlife Management biologists, Robert Suydam and Craig George, on various occasions.

A Barrow resident knowledgeable about the mammals and fish of the area is expected to be included as a member of the marine mammal observer (MMO) team aboard the *Healy*. Although his primary duties will be as a member of the MMO team responsible for implementing the monitoring and mitigation requirements, he will also be able to act as liaison with hunters and fishers if they are encountered at sea. However, the proposed activity has been timed so as to avoid overlap with the main harvests of marine mammals (especially bowhead whales), and is not expected to affect the success of subsistence fishers.

The Plan of Cooperation will cover the initial phases of UAF's trans-Arctic Ocean seismic survey planned to occur in waters offshore of Barrow during August 2005. The purpose of this plan will be to identify measures that will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses, and to ensure good communication between the project scientists and the community of Barrow.

Subsequent meetings with whaling captains, other community representatives, the AEWC, the NSB and any other parties to the plan will be held as necessary to negotiate the terms of the plan and to coordinate planned seismic survey operation with subsistence whaling activity.

The proposed Plan of Cooperation may address the following:

- Operational agreement and communications procedures
- Where/when agreement becomes effective
- General communications scheme
- On-board Inupiat observer
- Conflict avoidance
- Seasonally sensitive areas
- Vessel navigation
- Air navigation
- Marine mammal monitoring activities
- Measures to avoid impacts to marine mammals
- Measures to avoid conflicts in areas of active whaling
- Emergency assistance
- Dispute resolution process

As noted above in § VIII, in the unlikely event that subsistence hunting or fishing is occurring within 5 km (3 mi) of the *Healy's* trackline, the airgun operations will be suspended until the *Healy* is >5 km away.

XIII. MONITORING AND REPORTING PLAN

> The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding...

UAF proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated monitoring requirements of the Incidental Harassment Authorization.

UAF's proposed Monitoring Plan is described below. UAF understands that this Monitoring Plan will be subject to review by NMFS and others, including discussions at the Beaufort Sea open-water review meeting that NMFS plans to convene on 10-12 May 2005 in Anchorage, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. UAF is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime hours and during any start ups of the airgun(s) at night. Airgun operations will be powered down or shut down when marine mammals are observed within, or about to enter, designated safety radii where there is a possibility of significant effects on hearing or other physical effects. Vessel-based MMOs will also watch for marine mammals (and, where they might occur, sea turtles) near the seismic vessel for at least 30 min prior to the planned start of airgun operations after an extended shut down of the airgun. When feasible, observations will also be made during daytime periods without seismic operations (e.g., during transits and during coring operations).

During seismic operations across the Arctic Ocean, four observers will be based aboard the vessel. MMOs will be appointed by UAF with NMFS concurrence. A Barrow resident knowledgeable about the mammals and fish of the area is expected to be included in the MMO team aboard the *Healy.* At least one observer, and when practical two observers, will monitor marine mammals near the seismic vessel during ongoing daytime operations and nighttime start ups of the airgun. Use of two simultaneous observers will increase the proportion of the animals present near the source vessel that are detected. MMO(s) will normally be on duty in shifts of duration no longer than 4 hours. At least one MMO is expected to be an Inupiat. The USCG crew will also be instructed to assist in detecting marine mammals and implementing mitigation requirements (if practical). Before the start of the seismic survey the crew will be given additional instruction on how to do so.

The *Healy* is a suitable platform for marine mammal observations. When stationed on the flying bridge, the eye level will be ~27.7 m (91 ft) above sea level, and the observer will have an unobstructed view around the entire vessel. If surveying from the bridge, the observer's eye level will be 19.5 m (64 ft) above sea level and ~25° of the view will be partially obstructed directly to the stern by the stack. During daytime, the MMO(s) will scan the area around the vessel systematically with reticle binoculars (e.g., 7 × 50 Fujinon) and with the naked eye. During darkness, NVDs will be available (ITT F500 Series Generation 3 binocular-image intensifier or equivalent), if and when required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. Those are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to animals directly.

When mammals are detected within or about to enter the designated safety radius, the airgun(s) will be powered down (or shut down if necessary) immediately. The observer(s) will continue to maintain watch to determine when the animal(s) are outside the safety radius. Airgun operations will not resume until the animal is outside the safety radius. The animal will be considered to have cleared the safety radius if it is visually observed to have left the safety radius, or if it has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm and beaked whales).

All observations and airgun shut downs will be recorded in a standardized format. Data will be entered into a custom database using a notebook computer. The accuracy of the data entry will be verified by computerized validity data checks as the data are entered and by subsequent manual checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical, or other programs for further processing and archiving.

Results from the vessel-based observations will provide

1. The basis for real-time mitigation (airgun shut down).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic study is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.

Reporting

A report will be submitted to NMFS within 90 days after the end of the cruise. The report will describe the operations that were conducted and the marine mammals that were detected near the operations. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report will summarize the dates and locations of seismic operations, and all marine mammal sightings (dates, times, locations, activities, associated seismic survey activities). The report will also include estimates of the amount and nature of potential "take" of marine mammals by harassment or in other ways.

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

UAF will coordinate the planned marine mammal monitoring program associated with the seismic survey in the Arctic Ocean (as summarized in § XIII) with other parties that may have interest in this area and/or be conducting marine mammal studies in the same region during operations. However, no other marine mammal studies are expected to occur in the planned study area at the proposed time. Nonetheless, UAF and NSF have coordinated, and will continue to coordinate, with other applicable Federal, State and Borough agencies and research groups, and with relevant researchers:

- USFWS Office of Marine Mammal Management, Anchorage. LGL has had preliminary contact with USFWS biologists on NSF's behalf regarding potential interactions with polar bears and walruses.
- Minerals Management Service, Alaska OCS Region, BWASP team (Bowhead Whale Aerial Survey Program). This team annually conducts aerial surveys for bowhead whales and other marine mammals in the Alaskan Beaufort Sea during autumn. LGL is in regular contact with the

BWASP team leader (Dr. C. Monnett) about this project. This project is not expected to begin until approx. 31 Aug., well after the *Healy* has left Alaskan waters.

- NSF-sponsored Shelf-Basin Interaction study, planned to continue in the general area during August 2005.
- Request to the State of Alaska confirming that the project is in compliance with state and local Coastal Management Programs.
- Coordination with the North Slope Borough Department of Wildlife Management Biologist, Craig George, concerning marine mammal and fisheries issues.
- Coordination with NOAA's Fisheries Biologist Larry Peltz concerning active fisheries in the study area and an EFH consultation.
- Coordination with representatives of subsistence hunters in Barrow with regard to potential concerns about interactions with subsistence hunting and negotiation of a "Plan of Cooperation", if required.

UAF, in conjunction with the USCG, is preparing an application for permission to conduct operations in the Norwegian EEZ. The marine science research application will be submitted through the U.S. State Department to the Norwegian Ministry of Foreign Affairs. Because of the Norwegian involvement in the project (University of Bergen personnel and equipment and NPD funding), no problem securing a permit is expected.

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APPENDIX A:
REVIEW OF POTENTIAL IMPACTS OF AIRGUN SOUNDS ON MARINE MAMMALS [5]

The following subsections review relevant information concerning the potential effects of airgun sounds on marine mammals. This information is included here as background for the briefer summary of this topic included in § VII of the IHA Application. This background material is little changed from corresponding subsections included in IHA Applications and EAs submitted to NMFS during 2003 and 2004 for other seismic survey projects. Much of this information has also been included in varying formats in other reviews, assessments, and regulatory applications prepared by LGL Ltd., environmental research associates. Because this review is intended to be of general usefulness, it includes references to types of marine mammals that will not be found in some specific regions.

(a) Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioral response, i.e., the mammals may tolerate it;
3. The noise may elicit behavioral reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions;
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, intermittent airgun or sonar pulses could cause masking for only a small proportion of the time, given the short duration of these pulses relative to the inter-pulse intervals;
6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

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(b) Hearing Abilities of Marine Mammals

The hearing abilities of marine mammals are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold at the frequency in question (the level of sound barely audible in the absence of ambient noise).
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency).
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (reviewed in Chapter 8 of Richardson et al. [1995] and in Au et al. [2000]). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are at present no specific data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that small odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The multi-beam sonar operated from the *Healy* emits pulsed sounds at 12 kHz. That frequency is within or near the range of best sensitivity of many odontocetes. Thus, sound pulses from the multi-beam sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioral and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small toothed whales that have been studied directly. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic (or sonar) sounds would be detectable and yet often show no overt reaction to those sounds. Behavioral responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioral reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995; McCauley et al. 2000a; Johnson 2002).

Pinnipeds

Underwater audiograms have been obtained using behavioral methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, better auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30–50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 µPa. Measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1 µPa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal (not an Atlantic/Gulf of Mexico species) appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

For the otariid (eared) seals, the high frequency cutoff is lower than for phocinids, and sensitivity at low frequencies (e.g., 100 Hz) is poorer than for hair seals (harbor or elephant seal).

The underwater hearing of a walrus has recently been measured at frequencies from 125 Hz to 15 kHz (Kastelein et al. 2002). The range of best hearing was from 1–12 kHz, with maximum sensitivity (67 dB re 1 µPa) occurring at 12 kHz (Kastelein et al. 2002).

Sirenians

The hearing of manatees is sensitive at frequencies below 3 kHz. A West Indian manatee that was tested using behavioral methods could apparently detect sounds from 15 Hz to 46 kHz (Gerstein et al. 1999). Thus, manatees may hear, or at least detect, sounds in the low-frequency range where most seismic energy is released. It is possible that they are able to feel these low-frequency sounds using vibrotactile receptors or because of resonance in body cavities or bone conduction.

Based on measurements of evoked potentials, manatee hearing is apparently best around 1–1.5 kHz (Bullock et al. 1982). However, behavioral testing suggests their best sensitivity is at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

(c) Characteristics of Airgun Pulses

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. The resulting downward-directed pulse has a duration of only 10 to 20 ms, with only one strong positive and one strong negative peak pressure (Caldwell and Dragoset 2000). Most energy emitted from airguns is at relatively low frequencies. For example, typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain some energy up to 500–1000 Hz and above (Goold and Fish 1998). The pulsed sounds associated with seismic exploration have higher peak levels than other industrial sounds to which whales and other marine mammals are routinely exposed. The only sources with higher or comparable effective source levels are explosions.

The peak-to-peak source level of the airgun configurations to be used by UAF during the project is ~241 dB re 1 μPa at 1 m, considering the frequency band up to about 250 Hz. This is the nominal source level applicable to downward propagation. The effective source level for horizontal propagation is lower. The peak-to-peak source levels of the 2- to 20-airgun arrays used during various L-DEO projects have peak-to-peak source levels ranging from 236 to 263 dB re 1 μPa at 1 m. The only man-made sources with effective source levels as high as (or higher than) a large array of airguns are explosions and high-power sonars operating near maximum power.

Several important mitigating factors need to be kept in mind. ***(1)*** Airgun arrays produce intermittent sounds, involving emission of a strong sound pulse for a small fraction of a second followed by several seconds of near silence. In contrast, some other sources produce sounds with lower peak levels, but their sounds are continuous or discontinuous but continuing for much longer durations than seismic pulses. ***(2)*** Airgun arrays are designed to transmit strong sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-target areas. ***(3)*** An airgun array is a distributed source, not a point source. The nominal source level is an estimate of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array. That figure is useful in calculating the expected received levels in the far field, i.e., at moderate and long distances. Because the airgun array is not a single point source, there is no one location within the near field (or anywhere else) where the received level is as high as the nominal source level.

The strengths of airgun pulses can be measured in different ways, and it is important to know which method is being used when interpreting quoted source or received levels. Geophysicists usually quote peak-to-peak levels, in bar-meters or (less often) dB re 1 μPa · m. The peak (= zero-to-peak) level for the same pulse is typically about 6 dB less. In the biological literature, levels of received airgun pulses are often described based on the "average" or "root-mean-square" (rms) level, where the average is calculated over the duration of the pulse. The rms value for a given airgun pulse is typically about 10 dB lower than the peak level, and 16 dB lower than the peak-to-peak value (Greene 1997; McCauley et al. 1998, 2000a). A fourth measure that is sometimes used is the energy level, in dB re 1 μPa2 · s. Because the pulses are <1 s in duration, the numerical value of the energy is lower than the rms pressure level, but the units are different. Because the level of a given pulse will differ substantially depending on which of these measures is being applied, it is important to be aware which measure is in use when interpreting any quoted pulse level. In the past, NMFS has commonly referred to rms levels when discussing levels of pulsed sounds that might "harass" marine mammals.

Seismic sound received at any given point will arrive via a direct path, indirect paths that include reflection from the sea surface and bottom, and often indirect paths including segments through the bottom sediments. Sounds propagating via indirect paths travel longer distances and often arrive later than sounds arriving via a direct path. (However, sound traveling in the bottom may travel faster than that in the water, and thus may, in some situations, arrive slightly earlier than the direct arrival despite traveling a greater distance.) These variations in travel time have the effect of lengthening the duration of the received pulse. Near the source, the predominant part of a seismic pulse is about 10 to 20 ms in duration. In comparison, the pulse duration as received at long horizontal distances can be much greater. For example, for one airgun array operating in the Beaufort Sea, pulse duration was about 300 ms at a distance of 8 km (4.3 n.mi.), 500 ms at 20 km (10.8 n.mi.), and 850 ms at 73 km or 39.4 n.mi. (Greene and Richardson 1988).

Another important aspect of sound propagation is that received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995). Paired measurements of received airgun sounds at depths of 3 m (9.8 ft) vs. 9 m (29.5 ft) or 18 m (59 ft) have shown that received levels are typically several decibels lower at 3 m (Greene and Richardson 1988). For a mammal whose auditory organs are within 0.5 or 1 m (1.6–3.3 ft) of the surface, the received level of the predominant low-frequency components of the airgun pulses would be further reduced. In deep water, the received levels at deep depths can be considerably higher than those at relatively shallow (e.g., 18 m) depths and the same horizontal distance from the airguns (Tolstoy et al. 2004a,b).

Pulses of underwater sound from open-water seismic exploration are often detected 50–100 km (27–54 n.mi.) from the source location, even during operations in nearshore waters (Greene and Richardson 1988; Burgess and Greene 1999). At those distances, the received levels are low—below 120 dB re 1 μPa on an approximate rms basis. However, faint seismic pulses are sometimes detectable at even greater ranges (e.g., Bowles et al. 1994; Fox et al. 2002). Considerably higher levels can occur at distances out to several kilometers from an operating airgun array.

(d) Masking Effects of Seismic Surveys

Masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999; Nieukirk et al. 2004). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). That has also been shown during recent work in the Gulf of Mexico (Tyack et al. 2003). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 Hz. These low frequencies are mainly used by mysticetes, but generally not by odontocetes, pinnipeds, or sirenians. An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the marine mammal signal. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of many marine mammals vs. airgun sounds, communication and echolocation are not expected to be disrupted. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; reviewed in Richardson et al. 1995:233*ff,* 364*ff*). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking.

(e) Disturbance by Seismic Surveys

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause "Level B" harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

There has been debate regarding how substantial a change in behavior or mammal activity is required before the animal should be deemed to be "taken by Level B harassment". NMFS has stated that

> "…a simple change in a marine mammal's actions does not always rise to the level of disruption of its behavioral patterns. … If the only reaction to the [human] activity on the part of the marine mammal is within the normal repertoire of actions that are required to carry out that behavioral pattern, NMFS considers [the human] activity not to have caused a disruption of the behavioral pattern, provided the animal's reaction is not otherwise significant enough to be considered disruptive due to length or severity. Therefore, for example, a short-term change in breathing rates or a somewhat shortened or lengthened dive sequence that are within the animal's normal range and that do not have any biological significance (i.e., do no disrupt the animal's overall behavioral pattern of breathing under the circumstances), do not rise to a level requiring a small take authorization." (NMFS 2001, p. 9293).

Based on this guidance from NMFS, we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Behavioral reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The definitions of "taking" in the U.S. Marine Mammal Protection Act, and its applicability to various activities, were slightly altered for military and and federal scientific research activities recently (November 2003). Also, the U.S. National Marine Fisheries Service is proposing to replace current Level A and B harassment criteria with guidelines based on exposure characteristics that are specific to species and sound types. Four public meetings are being conducted through January 2005 across the nation to consider the impact of implementing new criteria for what constitutes a "take" of marine mammals. Thus, for projects subject to U.S. jurisdiction, changes in procedures may be required in the near future.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. Some of the main studies and reviews on this topic are the following: Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999; Gordon et al. 2004).

Prior to the late 1990s, it was thought that bowhead whales, gray whales, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 μPa rms, but that subtle behavioral changes sometimes become evident at somewhat lower received levels. Recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) may show strong avoidance at received levels somewhat lower than 160–170 dB re 1 μPa rms. The observed avoidance reactions involved movement away from feeding locations or statistically significant deviations in the whales' direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Humpback Whales.—McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun 2678-in^3 array, and to a single 20 in^3 airgun with source level 227 dB re 1 μPa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single gun. Avoidance reactions began at 5–8 km (2.7–4.3 n.mi.) from the array and those reactions kept most pods about 3–4 km (1.6–2.2 n.mi.) from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km (7.6 n.mi.). Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 μPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The standoff range, i.e., the closest point of approach of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of 5–8 km (2.7–4.3 n.mi.) from the airgun array and 2 km (1.1 n.mi.) from the single gun. However, some individual humpback whales, especially males, approached within distances 100–400 m (328–1312 ft), where the maximum received level was 179 dB re 1 μPa rms.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis.

Bowhead Whales.—Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6 to 99 km (3–53 n.mi.) and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. However, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis. Bowheads usually did show strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km or 1.6–3.8 n.mi.) and when received levels of airgun sounds were 152–178 dB (Richardson et al. 1986, 1995; Ljungblad et al. 1988). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa·m at a distance of 7.5 km (4 n.mi.), and swam away when it came within about 2 km (1.1 n.mi.). Some whales continued feeding until the vessel was 3 km (1.6 n.mi.) away. This work, and a more recent study by Miller et al. (2005), show that feeding bowhead whales tend to tolerate higher sound levels than migrating whales before showing an overt change in behavior. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996–98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km (10.8–16.2 n.mi.), and that few bowheads approached within 20 km (10.8 n.mi.). Received sound levels at those distances were only 116–135 dB re 1 μPa (rms). Some whales apparently began to deflect their migration path when still as much as 35 km (19 n.mi.) away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12–24 h after seismic shooting stopped. These and other data suggest that migrating bowhead whales are more responsive to seismic pulses than were summering bowheads.

Gray Whales.—Malme et al. (1986, 1988) studied the responses of feeding eastern gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6 to 2.8 km (1.4–1.5 n.mi.) from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 µPa and higher, on an approximate rms basis. The 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km (1.3 n.mi.) from a 4000-in³ array operating off central California (CPA = closest point of approach). This would occur at an average received sound level of about 170 dB (rms). Some slight behavioral changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001. However, there were indications of subtle behavioral effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002).

Rorquals.—Blue, sei, fin, and minke whales have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of about 1.6 km (0.9 n.mi.) from the array during shooting and 1.0 km (0.5 n.mi.) during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

Discussion and Conclusions.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, recent studies of humpback and especially migrating bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 µPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the seismic array.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

Toothed Whales

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales, and none similar in size and scope to the studies of humpback, bowhead, and gray whales mentioned above. However, systematic work on sperm whales is underway.

Delphinids and Similar Species.—Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of operating seismic vessels. Authors reporting cases of small toothed whales close to the operating airguns have included Duncan (1985), Arnold (1996), and Stone (2003). When a 3959 in^3, 18-airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel regardless of whether the guns were firing. However, in Puget Sound, Dall's porpoises observed when a 6000 in^3, 12–16-airgun array was firing tended to be heading away from the boat (Calambokidis and Osmek 1998).

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180-m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km (0.5 n.mi.) radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003; Gordon et al. 2004). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km (0.3 n.mi.) or more for most species groups. Killer whales also appear to be more tolerant of seismic shooting in deeper waters.

For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the United Kingdom in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel, etc.) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including white-beaked dolphins, *Lagenorhynchus* spp., and other dolphin spp. showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp., harbor porpoises, and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

Captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and white whale to single impulses from a watergun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviors were exhibited by captive bottlenose dolphins and a white whale exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviors in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting the aversive behaviors mentioned above.

Observations of odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be relevant as an indicator of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were "not always effective" in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for TTS, the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Beaked Whales.—There are no specific data on the behavioral reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001). However, those vessels were not emitting airgun pulses.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There has been a recent (Sept. 2002) stranding of Cuvier's beaked whales in the Gulf of California (Mexico) when the L-DEO vessel *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002). Another stranding of Cuvier's beaked whales in the Galapagos occurred during a seismic survey in April 2000; however "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry [ed.] 2002). The evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

Sperm Whales.—All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km or 162 n.mi.) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in U.K. waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. However, the U.K. results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa pk-pk (Madsen et al. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002; Jochens and Biggs 2003), along with a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys (Mate 2003). During two controlled exposure experiments where sperm whales were exposed to seismic pulses at received levels 143–148 dB re 1 μPa, there was no indication of avoidance of the vessel or changes in feeding efficiency (Jochens and Biggs 2003). The received sounds were measured on an "rms over octave band with most energy" basis (P. Tyack, pers. comm. to LGL Ltd.); the broadband rms value would be somewhat higher. Although the sample size from the initial work was small (four whales during two experiments), the results are consistent with those off northern Norway.

Conclusions.—Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the U.K., show localized avoidance. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown.

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies in recent years. Monitoring studies in the Beaufort Sea during 1996–2001 provide a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Pinnipeds exposed to seismic surveys have also been observed during recent seismic surveys along the USWW. Some limited data are available on physiological responses of seals exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the United Kingdom, a radio-telemetry study has demonstrated short-term changes in the behavior of harbor (=common) seals and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioral responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km (1.3 n.mi.) from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioral response, even when the array was within 500 m (1641 ft). All grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behavior modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998).

Monitoring work in the Alaskan Beaufort Sea during 1996–2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating then when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundreds of meters, and many seals remained within 100–200 m (328–656 ft) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviors, e.g. "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

Fissipeds.—Behavior of sea otters along the California coast was monitored by Riedman (1983, 1984) while they were exposed to a single 100 in^3 airgun and a 4089 in^3 array. No disturbance reactions were evident when the airgun array was as close as 0.9 km. Otters also did not respond noticeably to the single airgun. The results suggest that sea otters are less responsive to marine seismic pulses than are baleen whales. Also, sea otters spend a great deal of time at the surface feeding and grooming. While at the surface, the potential noise exposure of sea otters would be much reduced by the pressure release effect at the surface.

(f) Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this in the case of exposure to sounds from seismic surveys. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shutdown) radii planned for numerous seismic surveys. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed below,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid Temporary Threshold Shift (TTS) let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

Several aspects of the monitoring and mitigation measures that are now often implemented during seismic survey projects are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. However, it is a temporary phenomenon, and is generally not considered to represent physical damage or "injury". Rather, the onset of TTS is an indicator that, if the animals is exposed to higher levels of that sound, physical damage is ultimately a possibility.

The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

Toothed Whales.—Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 μPa rms at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss; all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound pressure level) of 221 dB re 1 μPa produced no more than a slight and temporary reduction in hearing.

A similar study was conducted by Finneran et al. (2002) using an 80 in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 μPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value ~4 min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 μPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2000, 2002). In this study, TTS was defined as occurring when there was a 6 dB or larger increase in post-exposure thresholds; the reference to masking (MTTS) refers to the fact that these measurements were obtained under conditions with substantial (but controlled) background noise. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10–13 ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1 s or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With single short pulses, the TTS threshold appears to be (to a first approximation) a function of the energy content of the pulse (Finneran et al. 2002). The degree to which this generalization holds for other types of signals is unclear (Nachtigall et al. 2003). In particular, additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. Given the results of the afore-mentioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (~221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel.

To better characterize this radius, it would be necessary to determine the total energy that a mammal would receive as an airgun array approached, passed at various CPA distances, and moved away. (CPA = closest point of approach.) At the present state of knowledge, it would also be necessary to assume that the effect is directly related to total energy even though that energy is received in multiple pulses separated by gaps. The lack of data on the exposure levels necessary to cause TTS in toothed whales when the signal is a series of pulsed sounds, separated by silent periods, is a data gap

Baleen Whales.—There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale. However, in practice during seismic surveys, no cases of TTS are expected given the strong likelihood that baleen whales would avoid the approaching airguns (or vessel) before being exposed to levels high enough for there to be any possibility of TTS. (See above for evidence concerning avoidance responses by baleen whales.) This assumes that the ramp up (soft start) procedure is used when commencing airgun operations, to give whales near the vessel the opportunity to move away before they are exposed to sound levels that might be strong enough to elicit TTS. As discussed above, single-airgun experiments with bowhead, gray, and humpback whales show that those species do tend to move away when a single airgun starts firing nearby, which simulates the onset of a ramp up.

Pinnipeds.—TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) of underwater sound have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels (rms) of ~178 and 183 dB re 1 μPa and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, initial evidence from prolonged exposures suggested that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations. For sounds of relatively long duration (20–22 min), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100–2000 Hz range. Mild TTS became evident when the received levels were 60–75 dB above the respective hearing thresholds, i.e., at received levels of about 135–150 dB. Three of the five subjects showed shifts of ~4.6–4.9 dB and all recovered to baseline hearing sensitivity within 24 hours of exposure. Schusterman et al. (2000) showed that TTS thresholds of these seals were somewhat lower when the animals were exposed to the sound for 40 min than for 20–22 min, confirming that there is a duration effect in pinnipeds. There are some indications that, for corresponding durations of sound, some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999; Ketten et al. 2001; *cf.* Au et al. 2000). However, more recent indications are that TTS onset in the most sensitive pinniped species studied (harbor seal) may occur at a similar sound exposure level as in odontocetes (Kastak et al. 2004).

Likelihood of Incurring TTS.—A marine mammal within a radius of ≤100 m (≤328 ft) around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly. If some cetaceans did incur TTS through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see above). Pinnipeds occasionally seem to be attracted to operating seismic vessels. As previously noted, there are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. It is not known whether pinnipeds near operating seismic vessels, and especially those individuals that linger nearby, incur significant TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 μPa (rms). The corresponding limit for pinnipeds has been set at 190 dB, although the HESS Team (1999) recommended 180 dB for pinnipeds in California. The 180 and 190 dB (rms) levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before any TTS measurements for marine mammals were available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses stronger than 180 dB re 1 μPa rms. Furthermore, it should be noted that mild TTS is not injury, and in fact is a natural phenomenon experienced by marine and terrestrial mammals (including humans).

It has been shown that most large whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984–1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the initial stages of a ramp up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the likelihood that some mammals close to an airgun array might incur at least mild TTS (see Finneran et al. 2002), there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*).

Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002; Nachtigall et al. 2003). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). However, there is special concern about strong sounds whose pulses have very rapid rise times. In terrestrial mammals, there are situations when pulses with rapid rise times can result in PTS even though their levels are only a few dB higher than the level causing slight TTS. The rise time of airgun pulses is fast, but not nearly as fast as that of explosions, which are the main concern in this regard.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1 μPa (pk-pk) in odontocetes, then the PTS threshold might be as high as 240 dB re 1 μPa (pk-pk). In the units used by geophysicists, this is 10 bar-m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and pinnipeds may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Pinnipeds, on the other hand, often do not show strong avoidance of operating airguns.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. Commonly-applied monitoring and mitigation measures, including visual monitoring, course alteration, ramp ups, and power downs or shut downs of the airguns when mammals are seen within the "safety radii", would minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

(g) Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in a recent (2002) case, an L-DEO seismic survey, has raised the possibility that beaked whales may be especially susceptible to injury and/or behavioral reactions that can lead to stranding when exposed to strong pulsed sounds.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1 μPa, but the -53C briefly operated at an unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or perhaps died at sea (Balcomb and Claridge 2001).

Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24–25 September 2002 in the Canary Islands, where naval maneuvers were taking place. A recent paper concerning the Canary Islands stranding concluded that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, this might occur if they ascend unusually quickly when exposed to aversive sounds. Previously it was widely assumed that diving marine mammals are not subject to the bends or air embolism.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As discussed earlier, there has been a recent (Sept. 2002) stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a seismic survey by the L-DEO/NSF vessel R/V *Maurice Ewing* was underway in the general area (Malakoff 2002). The airgun array in use during that project was the *Ewing*'s 20-airgun 8490-in^3 array. This might be a first indication that seismic surveys can have effects, at least on beaked whales, similar to the suspected effects of naval sonars. However, the evidence linking the Gulf of California strandings to the seismic surveys is inconclusive, and to this date is not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multi-beam bathymetric sonar at the same time but, as discussed elsewhere, this sonar had much less potential than the aforementioned naval sonars to affect beaked whales. Although the link between the Gulf of California strandings and the seismic (plus multi-beam sonar) survey is inconclusive, this plus the various incidents involving beaked whale strandings "associated with" naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(h) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might theoretically occur in marine mammals exposed to strong underwater sound might include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays. However, there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations. Those could include cases when animals are exposed at close range for unusually long periods, or when the sound is strongly channeled with less-than-normal propagation loss, or when dispersal of the animals is constrained by shorelines, shallows, etc.

Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). However, there is essentially no information about the occurrence of noise-induced stress in marine mammals. Also, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. This is particularly so in the case of seismic surveys where the tracklines are long and/or not closely spaced, as is the case for most two-dimensional seismic surveys.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. There may also be a possibility that high sound levels could cause bubble formation in the blood of diving mammals that in turn could cause an air embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002).

Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. Jepson et al. (2003) suggested a possible link between mid-frequency sonar activity and acute and chronic tissue damage that results from the formation *in vivo* of gas bubbles in 14 beaked whales were stranded in the Canary Islands close to the site of an international naval exercise in September 2002. If cetaceans are susceptible to decompression sickness, that might occur if they ascend unusually quickly when exposed to aversive sounds. However, the interpretation that the effect was related to decompression injury is unproven (Piantadosi and Thalmann 2004; Fernández et al. 2004). Even if that effect can occur during exposure to mid-frequency sonar, there is no evidence that that type of effect occurs in response to airgun sounds. The only available information on acoustically-mediated bubble growth in marine mammals is modeling assuming prolonged exposure to sound.

As noted in the preceding subsection, a recent paper (Jepson et al. 2003) has suggested that cetaceans can at times be subject to decompression sickness. If so, this could be another mechanism by which exposure to strong sounds could, indirectly, result in non-auditory injuries and perhaps death.

In summary, very little is known about the potential for seismic survey sounds to cause either auditory impairment or other non-auditory physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

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